



Geant4: A Simulation toolkit

O. Stézowski and I. Companis



With many thanks to the Geant4 community !!!!

The roadmap of the week

Why?

What is It?

Geant 4



The roadmap of the week

Why?

This lecture, 1h30

What is It?

Geant 4



The roadmap of the week

Why?

This lecture, 1h30

What is It?

How
4 workshops
13h30

Geant 4



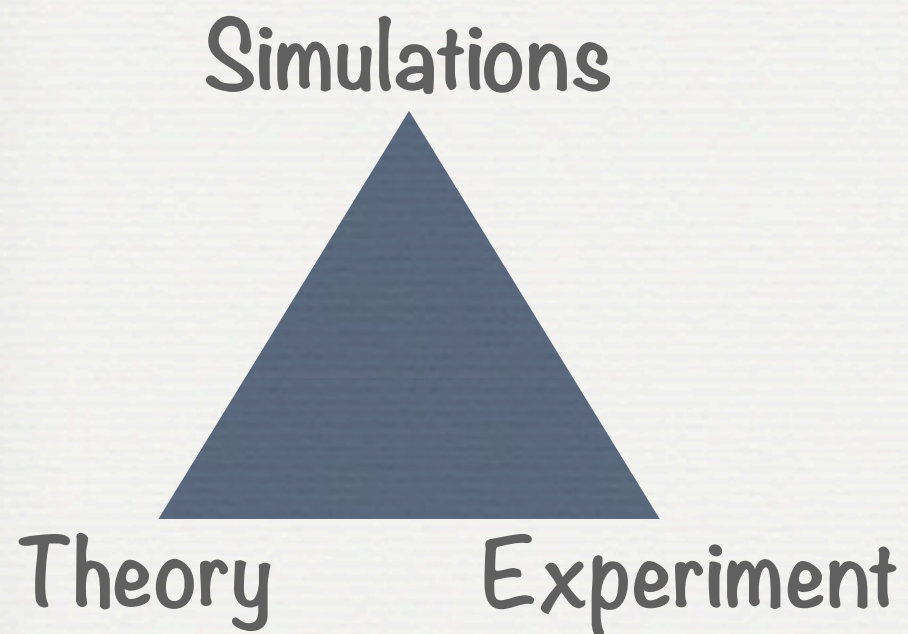


A personal, general view

More practical reasons

Why?

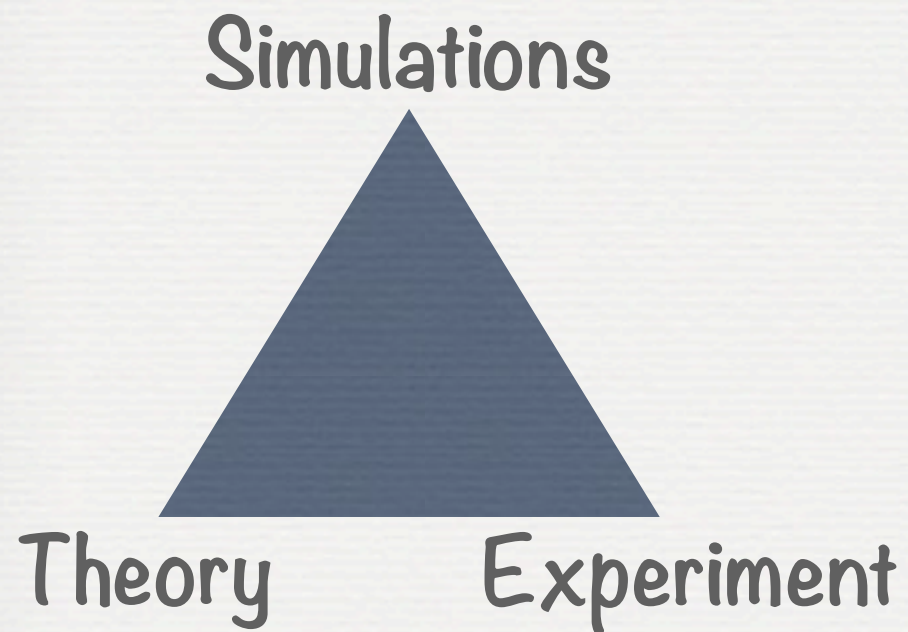
Why simulations ...



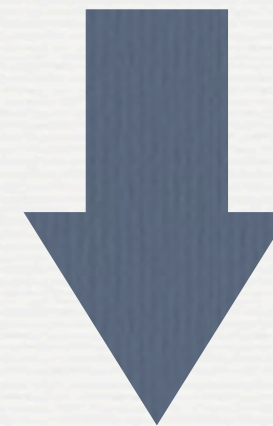
A guy, a seminar, somewhere:
place of simulations in physics

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Why simulations ...



A guy, a seminar, somewhere:
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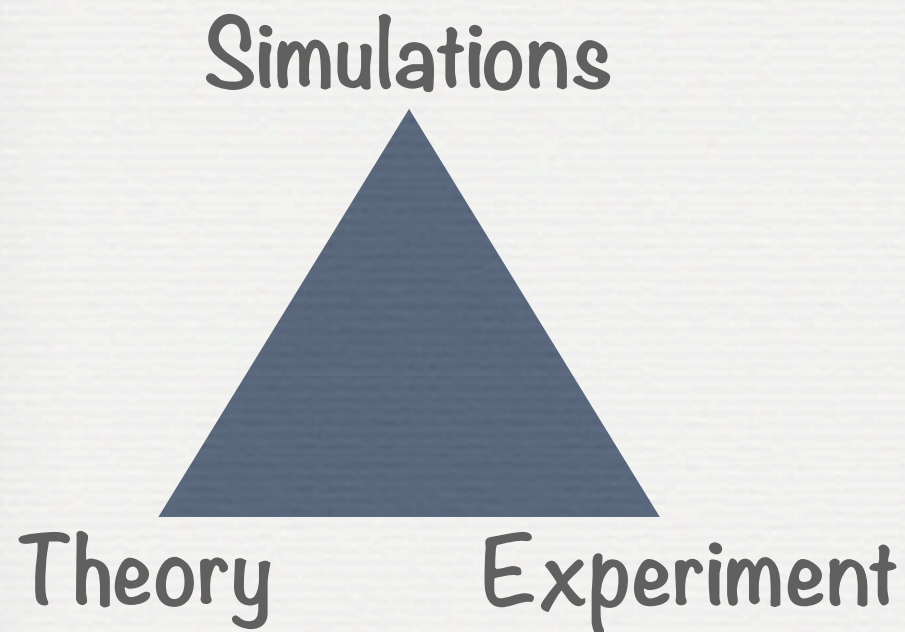
My View

common to all of us

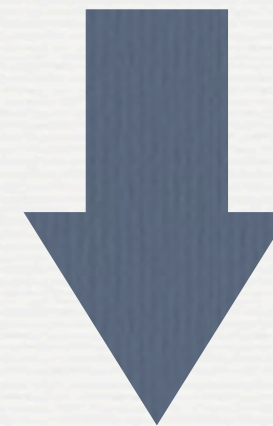
physicist

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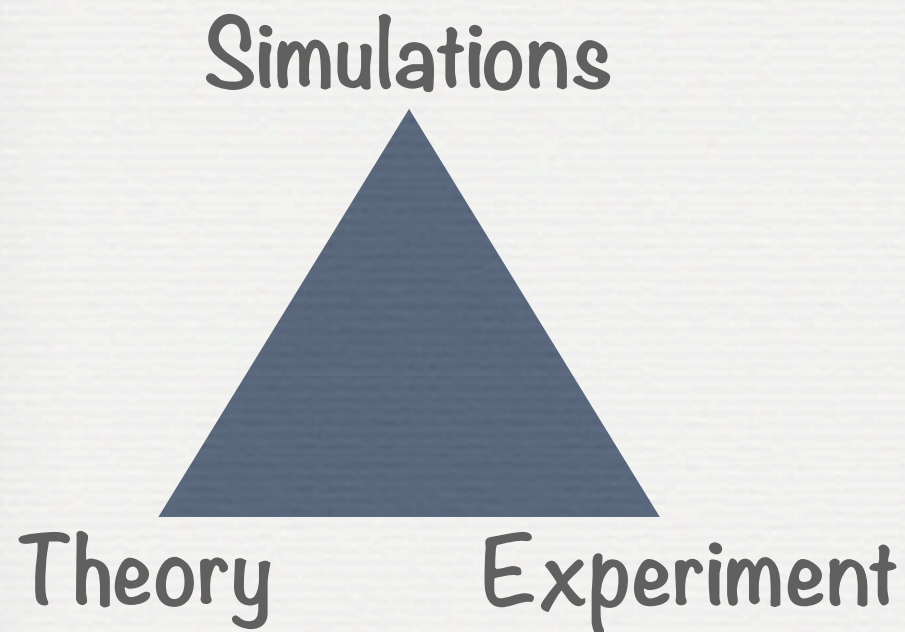
what we like to play with

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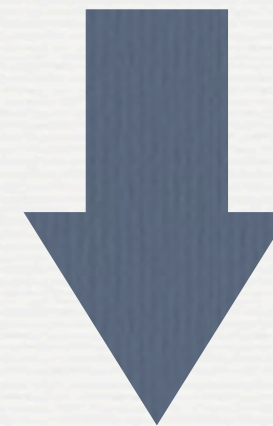
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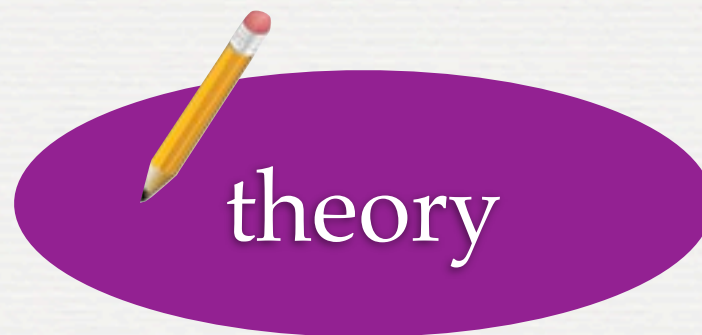
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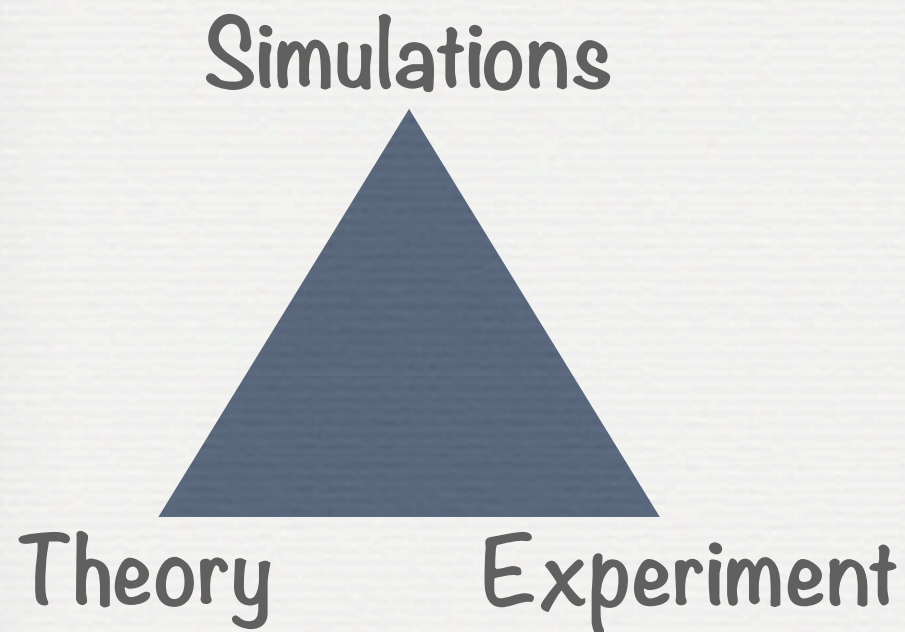
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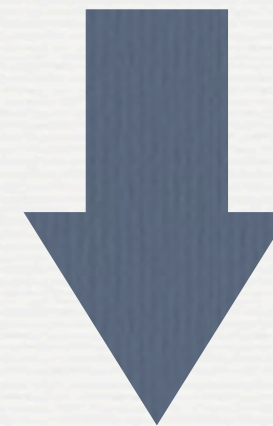
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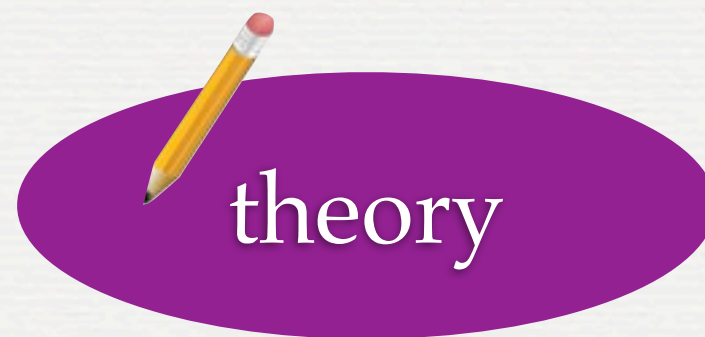
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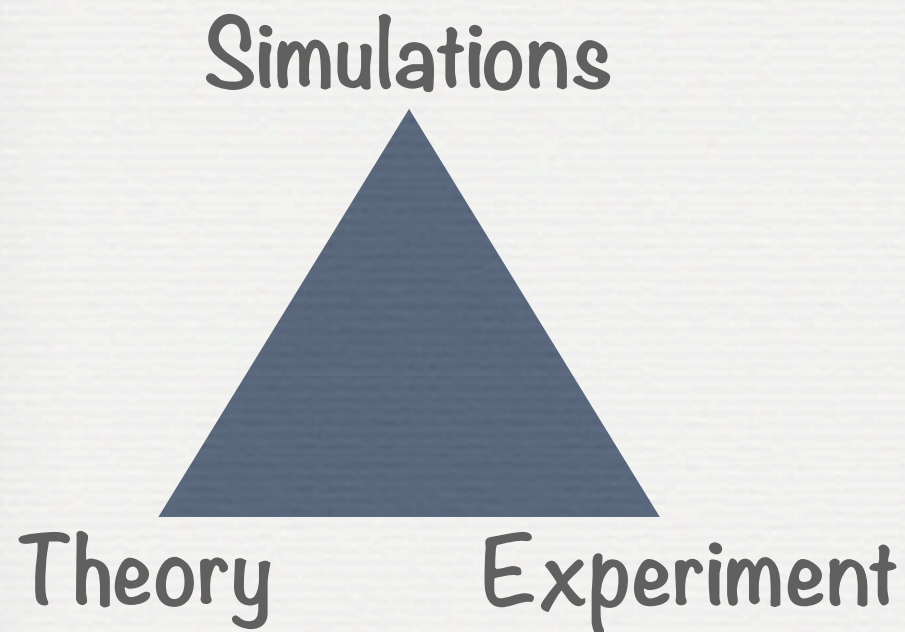
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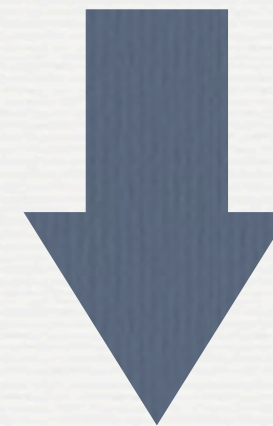
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physicist

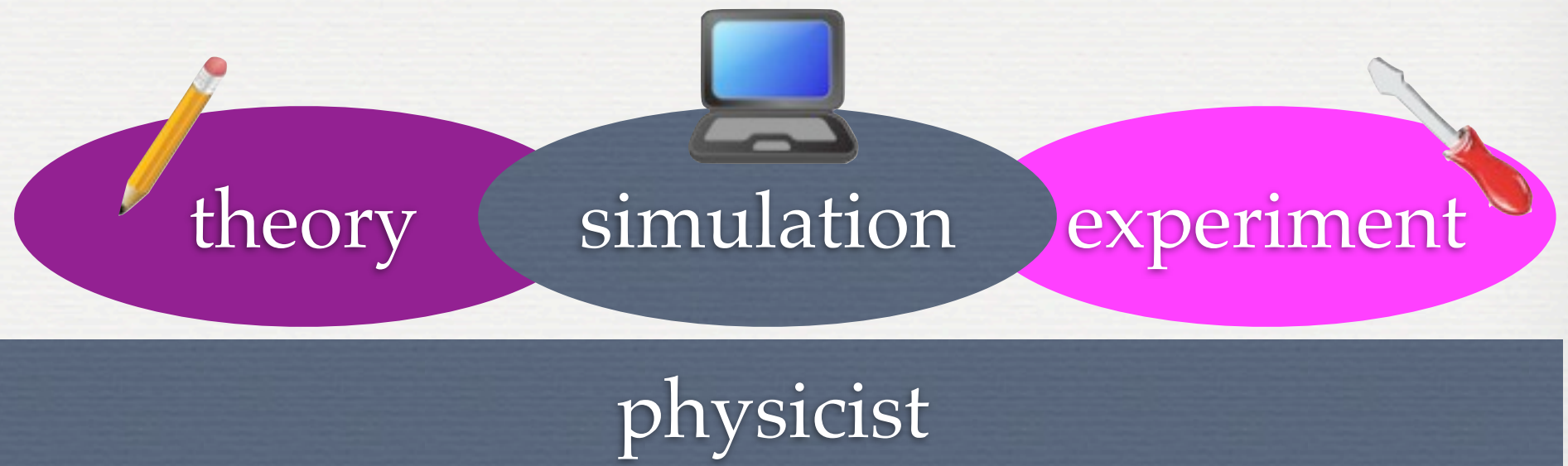
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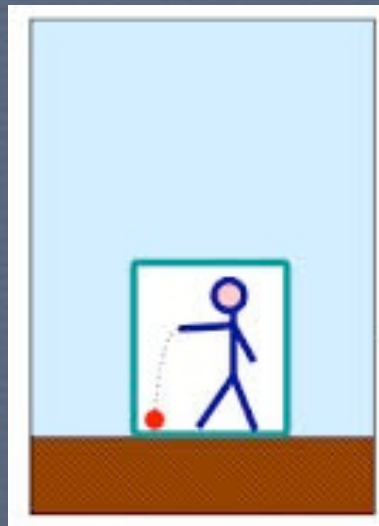
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common to all of us



Why?

Why simulations ...



what we like to play with

theory

simulation

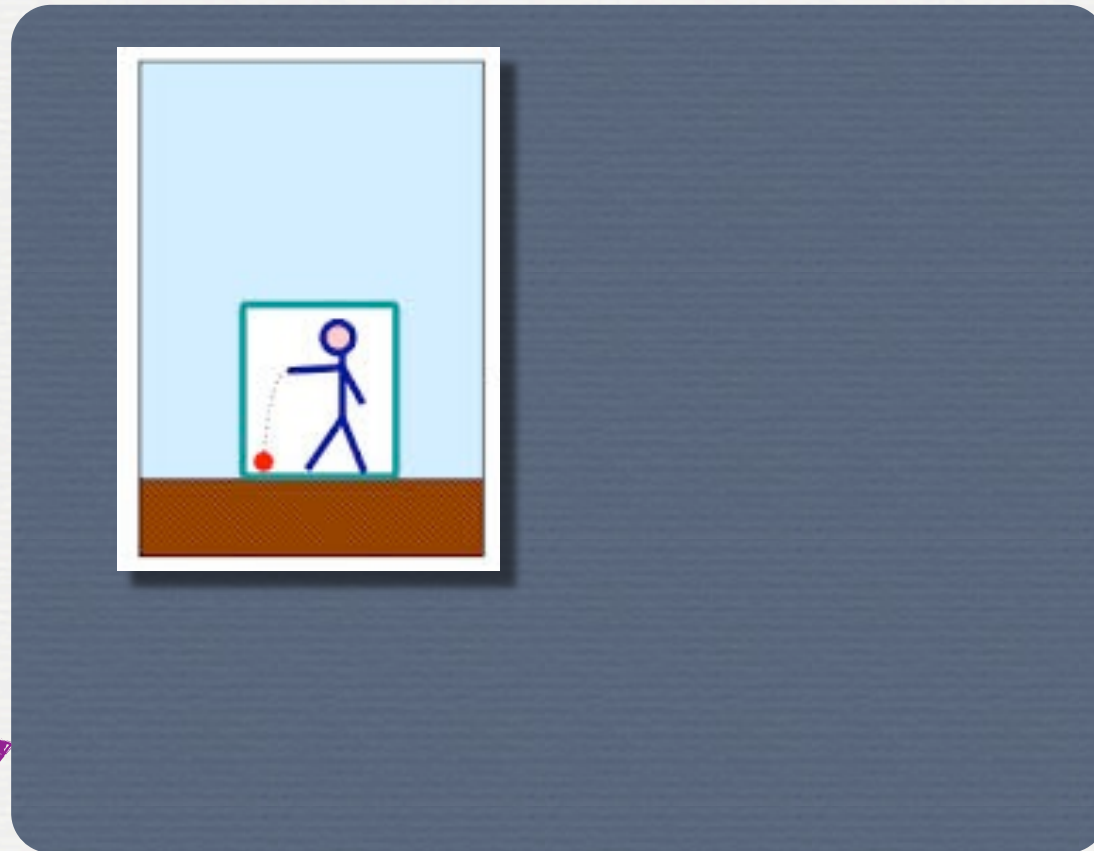
experiment

common to all of us

physicist

Why?

Why simulations ...



what we like to play with

common to all of us

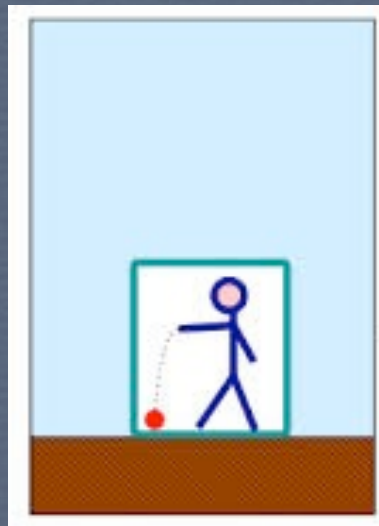


physicist

Why?

Why simulations ...

What if I change ...



what we like to play with

common to all of us

theory

simulation

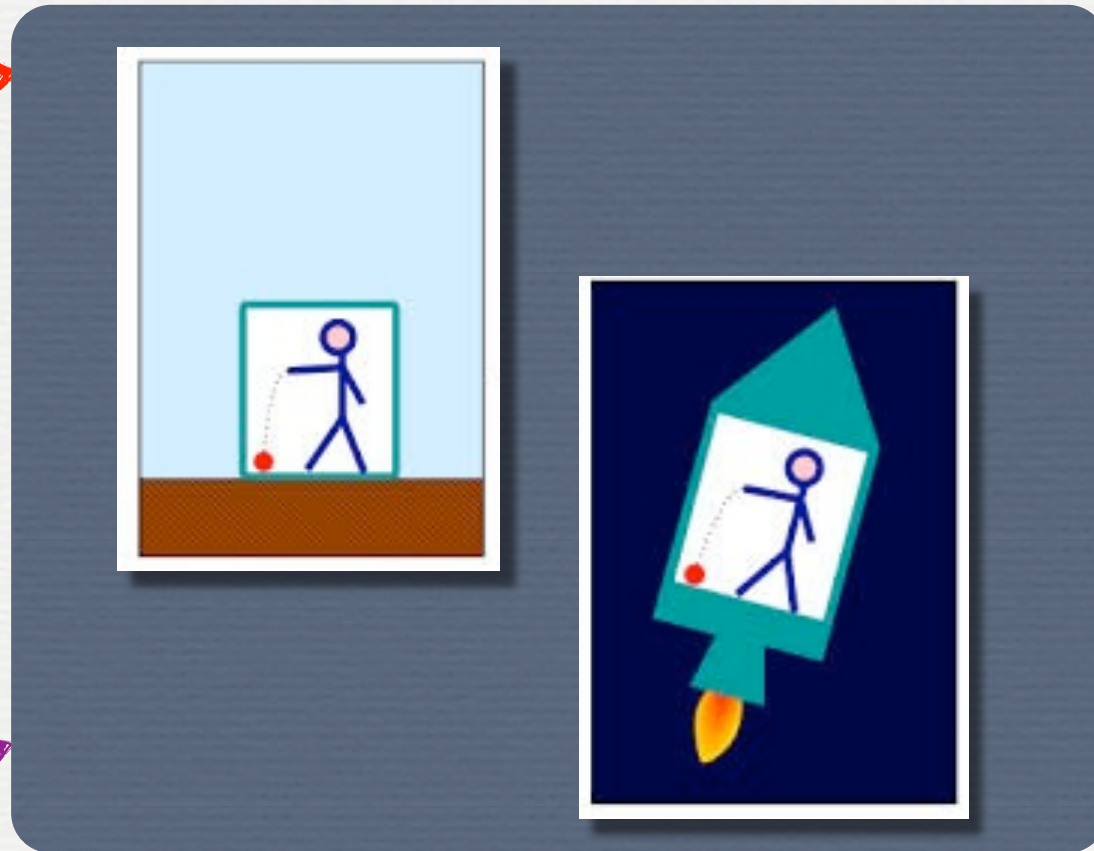
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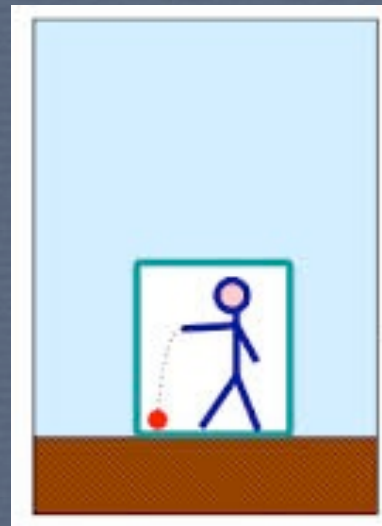
physicist

Why?

Why simulations ...

What if I change ...

Though experiment !!



what we like to play with

common to all of us

theory

simulation

experiment

physicist

Why?

Why simulations ...



It allows to be:

- ▶ less expensive
- ▶ quicker ... **well may be not** ...
- ▶ less dangerous
- ▶ ...



It allows to control everything:

- ▶ cause ➡ effect relationship
- ▶ step by step, more and more complexity
- ▶ step by step, more and more realism
- ▶ ...

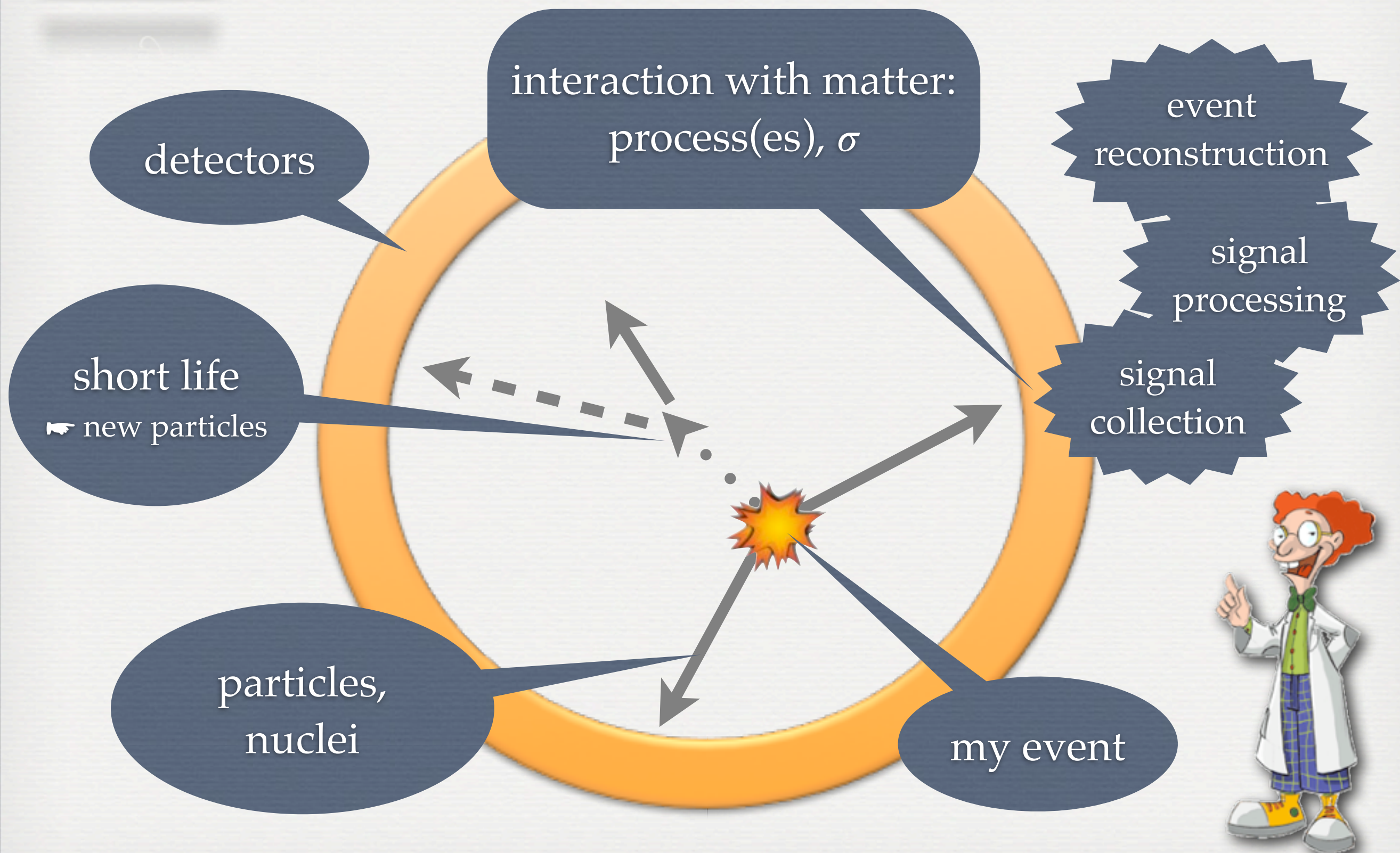


A personal, general view

More practical reasons

Why?

In our 'field', particles ...



Why?

Why simulations for us ...

- Detectors are:
 - ▶ more and more complex / precise
 - ▶ expansive ...
 - ▶ long time for R&D phase
 - ▶ long time to have them working well
- Events to be treated are:
 - ▶ complex
 - ▶ various
 - ▶ rare for the most interesting ones (background!)



Why simulations for us ...

« before » the detector is built

- to study new concepts
- establish raw performances*
- to study different triggers
- to optimize reconstructions
- to set experimental limits
- ...

➡ tools for R&D

* acceptance, response function ...

« during » the life of the detector

- to optimize experimental setup
signal ↗, background ↘, selection
- to understand problems in data
lost of efficiency, resolution
- to improve signal/background
- to improve physics models
- ...

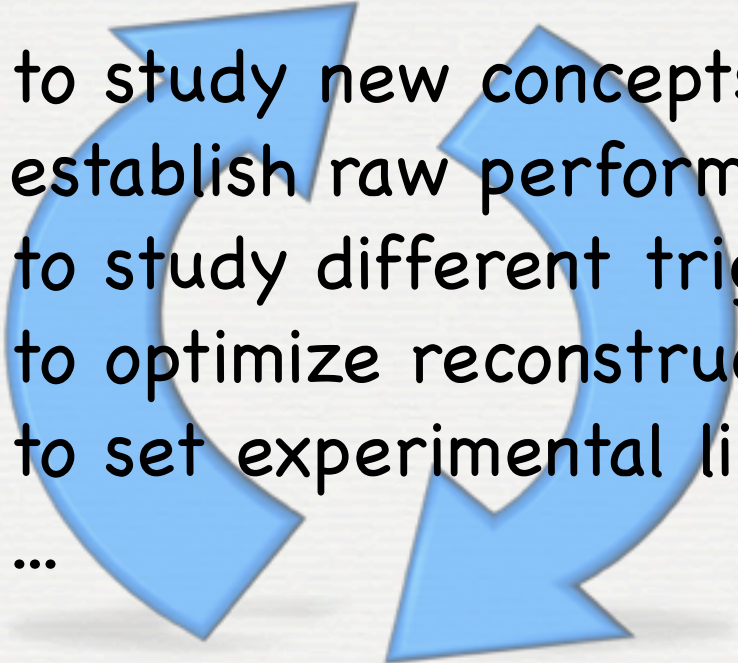
➡ to help for data analysis

➡ to understand physics

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Some general statements

Monte Carlo into the *game*

Geant4 some vocabulary

The Geant4 machine

What is It? Simulation landscape, some tools

- GEANT4 : GEometry ANd Tracking

→ <http://geant4.cern.ch/>

- FLUKA : FLUktuierende KAskade

alternative to Geant4

→ <http://www.fluka.org/fluka.php>

- MCNP(X) : Monte-Carlo N-Particle

More Nuclear Physics (Manhattan's project)

→ <http://mcnp.lanl.gov/>

Geant 4



mcnp



What is It? Simulation Landscape, many tools

EGS4, EGS5, EGSnrc

Geant3, Geant4

MARS

MCNP, MCNPX, A3MCNP, MCNP-DSP, MCNP4B

MVP, MVP-BURN

Penelope

Peregrine

Tripoli-3, Tripoli-3 A, Tripoli

DPM

EA-MC

FLUKA

GEM

HERMES

LAHET

MCBEND

MCU

MF3D

NMTC

MONK

MORSE

RTS&T-2000

SCALE

TRAX

VMC++

- pythia, herwig, hijing in particles ϕ
- evapor, fresco, empire in nuclear ϕ
- ...

physics generators

What is It? What is the Geant4 toolkit ?

Geant4 is the successor of Geant3 (fortran)

The project started in Dec '94 to face the LHC challenges

- First Public release Dec '98
- Currently 2-3 public release per year
- We are going to work with version 9.6.p02 [10.0.p02]



It is a **C++** (Object Oriented language) **Monte Carlo Simulation Toolkit**
↳ **Consequences ...** ↳ **basics covered in this lecture**

A variety of requirements taken into account in the design for applications in:
heavy ion physics, CP violation physics, cosmic-ray physics, astrophysics, space science, medical ...

To meet such requirements, **large degree of functionality and flexibility** provided
↳ Geant4 is not only for HEP but goes well beyond that.

We know a fraction

collaborations differ

Goal: to give you enough knowledge to work in your community !

user's doc

download area

user's forum

Geant 4

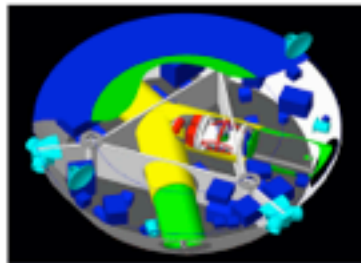
Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The two main reference papers for Geant4 are published in *Nuclear Instruments and Methods in Physics Research A* 501 (2003) 250-303, and *IEEE Transactions on Nuclear Science* 53 No. 1 (2006) 270-278.

Applications



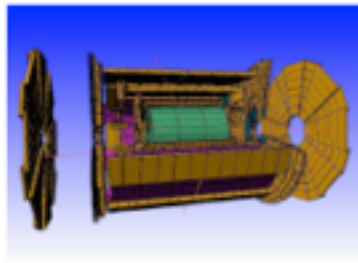
A sampling of applications, technology transfer and other uses of Geant4

User Support



Getting started, guides and information for users and developers

Results & Publications



Validation of Geant4, results from experiments and publications

Collaboration



Who we are: collaborating institutions, members, organization and legal information

[Download](#) | [User Forum](#) | [Gallery](#)
[Contact Us](#)

Search Geant4

News

- 28 June 2013 - **Release 10.0 BETA** is available from the [Beta download](#) area.
- 24 May 2013 - **Patch-02 to release 9.6** is available from the [download](#) area.
- 18 March 2013 - [2013 planned developments](#).
- 30 October 2012 - **Patch-02 to release 9.5** is available from the [archive download](#) area.

Events

- [Geant4 2013 International User Conference on Medicine and Biology applications](#), Bordeaux (F)
- [Past events](#)

news system

think your code as living 'object' !

Upgrade if needed

good practices in practical sessions

Major.Minor.[Patch]or[Beta]

Minor

- should not break your code
- new features / slightly different results

Major

- may (is likely to) break you code
- see release notes to help - warnings at running time

Patch: only bugs, no new features

Beta: to help the G4 community to develop ...

user's doc

Geant 4

[Home](#) > [User Support](#)

User Support

1. [Getting started](#)
2. [Training courses and materials](#)
3. [Source code](#)
 - a. [Download page](#)
 - b. [LXR code browser](#) -or- draft [doxygen documentation](#)
4. [Frequently Asked Questions \(FAQ\)](#)
5. [Bug reports and fixes](#)
6. [User requirements tracker](#)
7. [User Forum](#)
8. [Documentation](#)
 - a. [Introduction to Geant4](#)
 - b. [Installation Guide](#)
 - c. [Application Developers Guide](#)
 - d. [Toolkit Developers Guide](#)
 - e. [Physics Reference Manual](#)
 - f. [Software Reference Manual](#)
9. [Examples](#)
10. [Physics lists](#)
 - a. [Electromagnetic](#)
 - b. [Hadronic](#)
11. [User Aids](#)
 - a. [Tips for improving CPU](#)
 - b. [Process/model catalog](#)
 - c. [General particle source](#)
12. [Contact Coordinators & Contact](#)

Geant 4

Geant4 Cross Reference

Search Menu:

[geant4/](#) Browse the source code tree.

[File Name Search](#)

Search for files by name
(case sensitive).

[Full-Text Search](#)

Search through all the text.

[Identifier Search](#)

Find a class, method, variable, etc.

Geant4 User's Guide for Application

Geant4 Collaboration

Version: geant4 9.6.0

30th November, 2012

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- [1.2. How to use this manual](#)

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- [2.1.1. A Sample `main\(\)` Method](#)
- [2.1.2. `G4RunManager`](#)
- [2.1.3. User Initialization and Action Classes](#)
- [2.1.4. `G4UImanager` and UI CommandSubmission](#)
- [2.1.5. `G4cout` and `G4cerr`](#)

[2.2. How to Define a Detector Geometry](#)

- [2.2.1. Basic Concepts](#)
- [2.2.2. Create a Simple Volume](#)
- [2.2.3. Choose a Solid](#)
- [2.2.4. Create a Logical Volume](#)
- [2.2.5. Place a Volume](#)
- [2.2.6. Create a Physical Volume](#)
- [2.2.7. Coordinate Systems and Rotations](#)

[2.3. How to Specify Materials in the Detector](#)

Hi,

This is an interactive viewing and searching facility for the Geant4 source code.

It offers:

Source-tree browsing and file name search to easily find source files and navigate through the source directories.

Full-text indexing for fast retrieval of source files containing a given word or pattern.

Identifier cross-reference for fully hyperlinked source code. The names of classes, methods, and data can be clicked on to find the source files where they are defined and used.

The full-text indexing and retrieval are implemented using [Glimpse](#), so all the capabilities of Glimpse are available. Please see [Glimpse document](#) for details. Note that glimpse syntax is available for text and identifier searches. For file name search, please use regular expression.

Note

All source files are rendered into HTML. Do not attempt to download the Geant4 source code from this site!

Links

pdf also

organized in categories

user's forum

GEANT4 at hypernews.slac.stanford.edu Forum List by Category Not Logged In ([login](#))

Geant 4

Forums by Category	Recent Postings	Member Info	Overview
Forums by Time Order	Search in Forums	Members List	Contact Admin
Request a New Forum	Subscribe to Forums	New Member	

[Page Help](#)

Category: Applications

Educational Applications	Industrial instruments	Medical Applications	Space Applications
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Category: Control of runs, events, tracks, particles

Event and Track Management	Multithreading	Particles	Run Management
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Category: Experimental Setup

Biasing and Scoring	Fields: Magnetic and Otherwise	Geometry	Hits, Digitization and Pileup
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Category: General matters

Documentation and Examples	HyperNews System Announcements	Hypernews Testing	Installation and Configuration
User Requirements			

Category: Interfaces

(Graphical) User Interfaces	Analysis	Persistency	Visualization
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Category: Physics

Biasing and Scoring	Electromagnetic Processes	Fast Simulation, Transportation & Others	Hadronic Processes
Physics List	Processes Involving Optical Photons		

This site runs SLAC HyperNews version 1.11-slac-98, derived from the original HyperNews

<http://hypernews.slac.stanford.edu/HyperNews/geant4/cindex>

toolkit: do not hesitate to spend time in looking if things already exists !

- features / bugs known
- elegant solutions already found

[Overview](#)[Members](#)[Activities](#)[News](#)[Tutorials and teachings](#)[Conferences,
workshops and
meetings](#)[Geant4 Virtual Machine](#)[Jobs](#)[Useful links](#)[Publications](#)[The Geant4-DNA project](#)[The BioRad project](#)[BioRad Collaboration](#)[The BioRad II project](#)[BioRad II Collaboration](#)[Visualization & Qt](#)[Search](#)

On this website

On the whole CNRS Web

News front page

Geant4 9.6+P02 Virtual Machine now available for download

Download the software suite from the Geant4 for VMware section.

- Friday 31 May 2013 - [Read](#)

Geant4 2013 User Conference at the Physics-Medicine-Biology frontier

The Geant4 2013 International User Conference to be held in Bordeaux, France, from October 7th till October 11th, 2013 is announced. Registration is open. All details are available from (...)

- Monday 11 March 2013 - [Read](#)

Geant4 9.6+P01 Virtual Machine now available for download

Download the software suite from the Geant4 for VMware section.

- Tuesday 12 February 2013 - [Read](#)

Geant4 9.6 Virtual Machine now available for download

Download the software suite from the Geant4 for VMware section.

- Thursday 13 December 2012 - [Read](#)

Two post-doctoral positions available at CENBG

For more information , please consult the Jobs section.

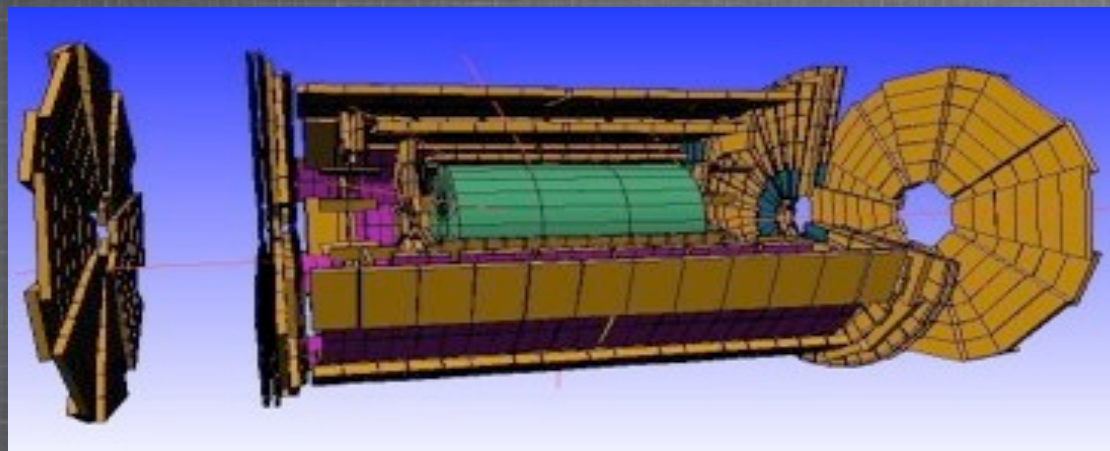
- Wednesday 5 December 2012 - [Read](#)

Geant4 workshop & tutorial in Wollongong U., Australia

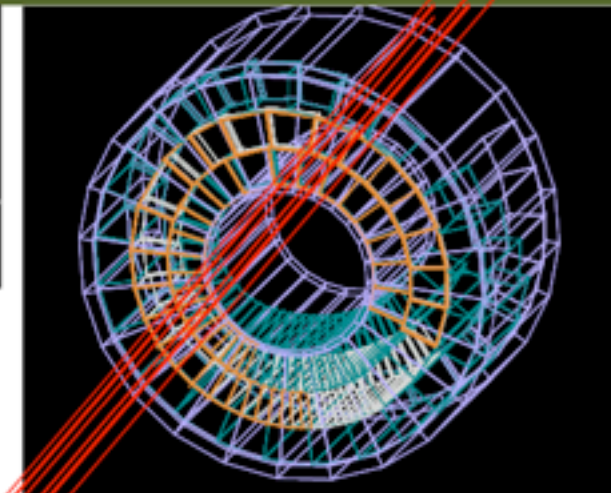
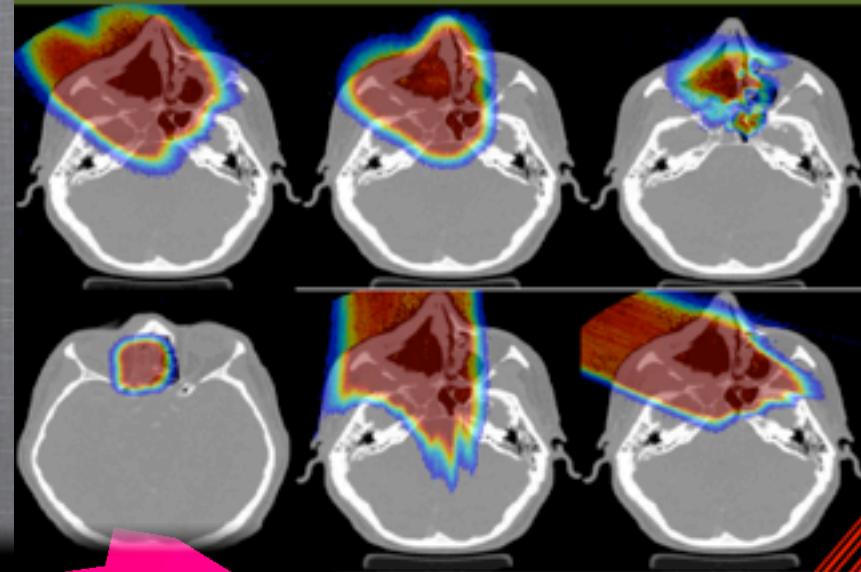
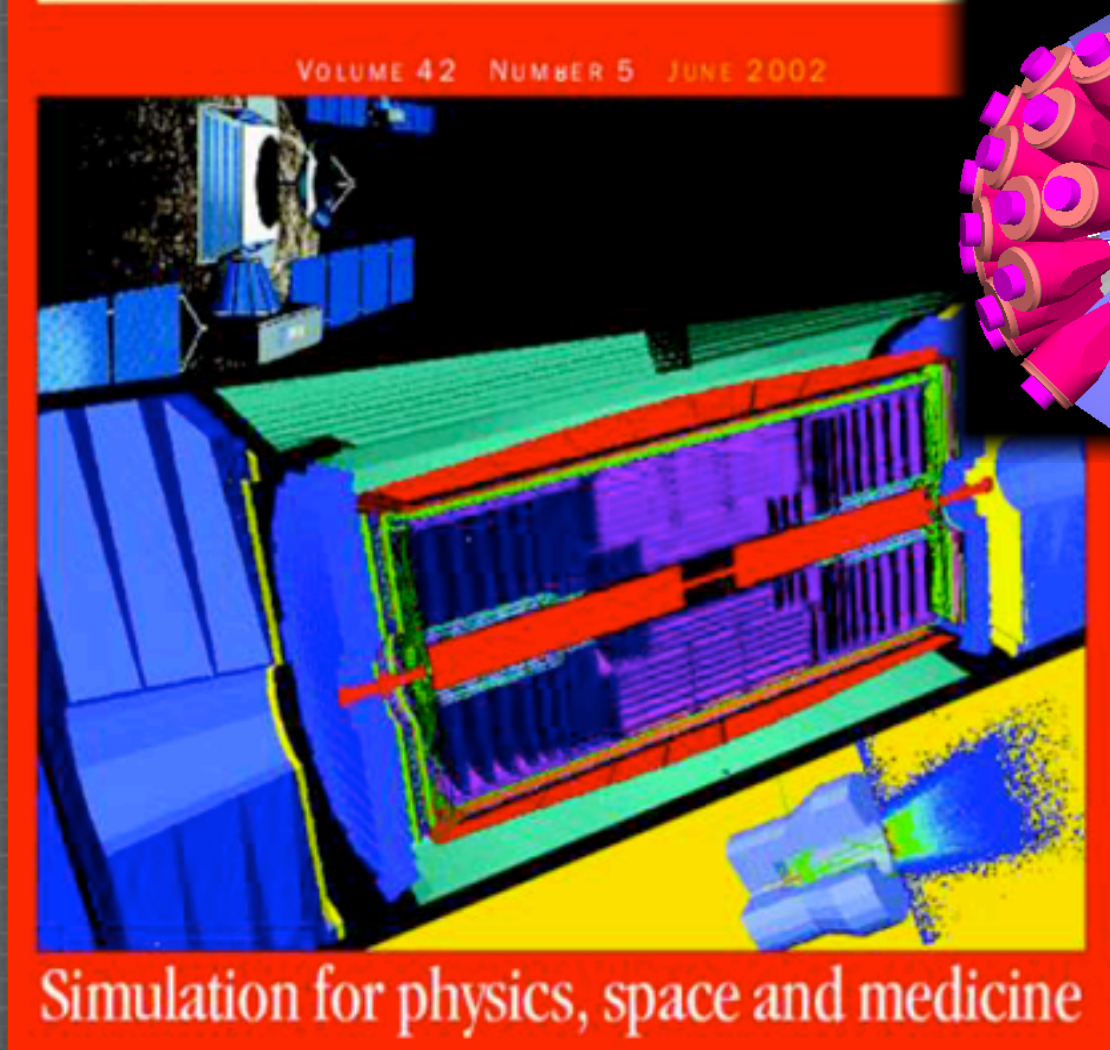
See more at this link

- Friday 23 November 2012 - [Read](#)

<http://geant4.in2p3.fr>



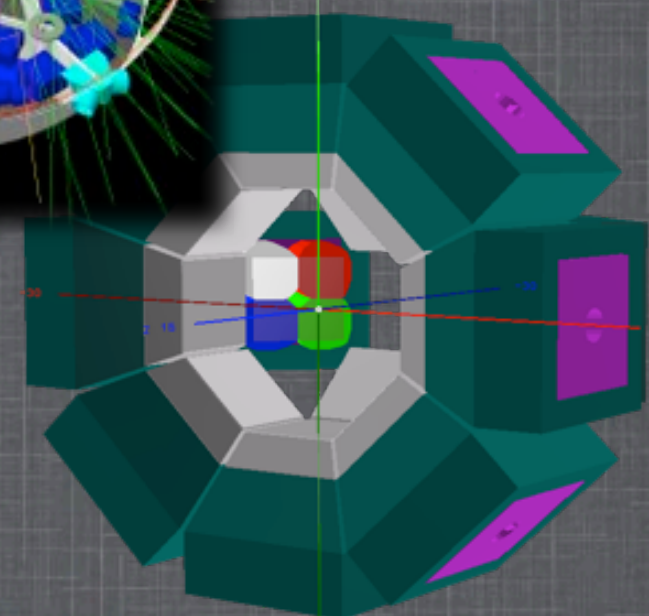
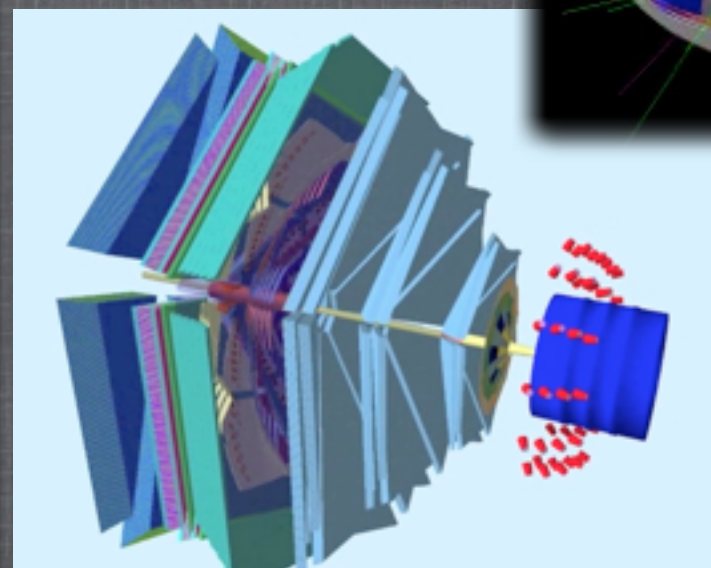
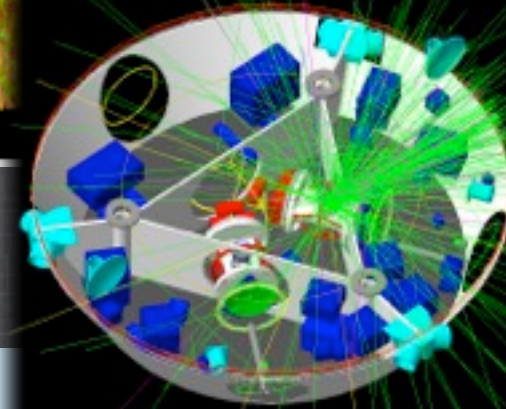
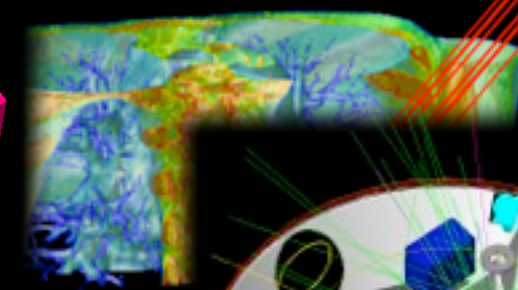
GEANT4 based proton dose calculation in a clinical environment: technical aspects, strategies and challenges



Harald Paganetti

MASSACHUSETTS
GENERAL HOSPITAL

HARVARD
MEDICAL SCHOOL





Some general statements

Monte Carlo into the *game*

Geant4 some vocabulary

The Geant4 machine

What is It?

Monte Carlo method ...

- At least one uniform generator required $[0,1[$

→ the random engine produce pseudo-random numbers ...



ROOT

<i>TRandom</i>	10^9	34 ns	linear congruential $X_{n+1} = (aX_n + C) \% m$
<i>TRandom1</i>	10^{171}	242 ns	RANLUX
<i>TRandom2</i>	10^{26}	37 ns	Tausworthe de l'Ecuyer
<i>TRandom3</i>	10^{6000}	45 ns	Mersenne Twister

+ initialization: **seed (reproducibility)** !

→ according to your needs. Do not run twice with same seed to add data ...

- With this one, more complex ones can be built >>>>



<http://root.cern.ch>

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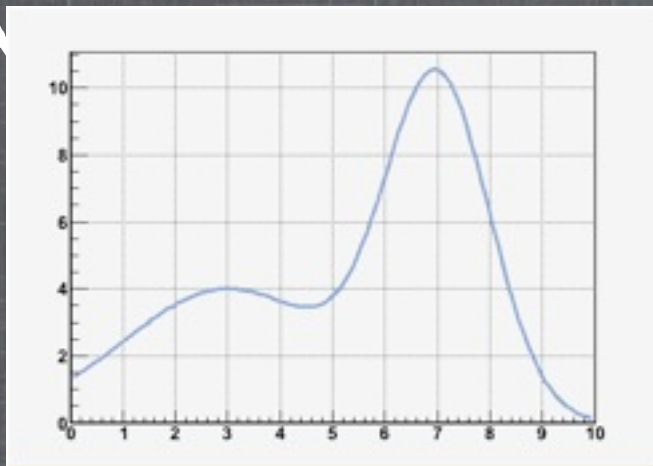
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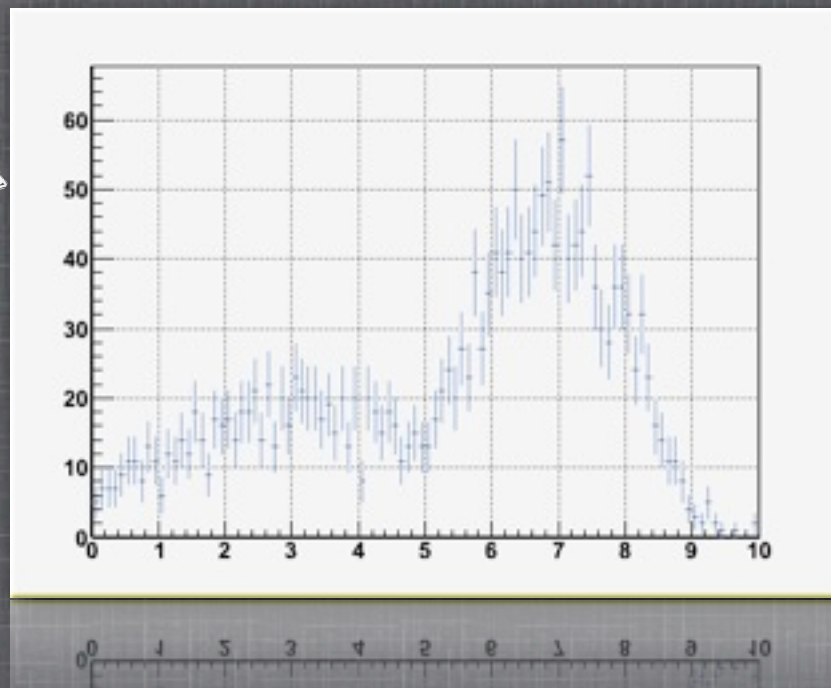
- if $f(x)$ is a probability density function -

Inverse Method

x uniform in $[0,1[\Rightarrow F^{-1}(x)$ is ' $f(x)$ distributed'
 $F^{-1} \leftarrow F$ cumulative distribution function

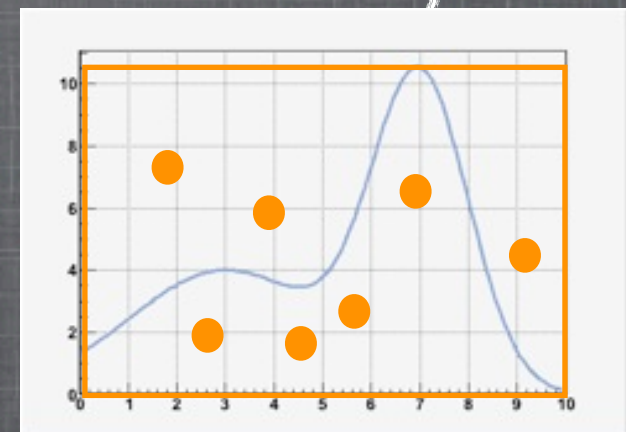


$$F(x) = \frac{\int^x f(u) du}{\int f(u) du}$$



Accept - Reject Method

(x_i, y_i) uniform in \square



accept x_i if $y_i < f(x_i)$
 $\rightarrow x_i$ ' $f(x)$ distributed' !

What is It?

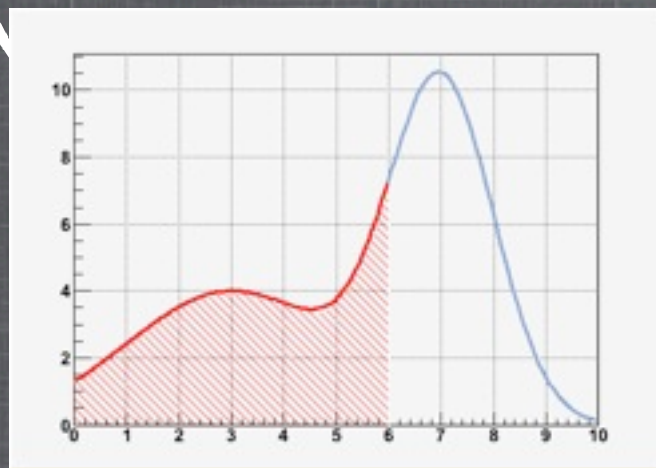
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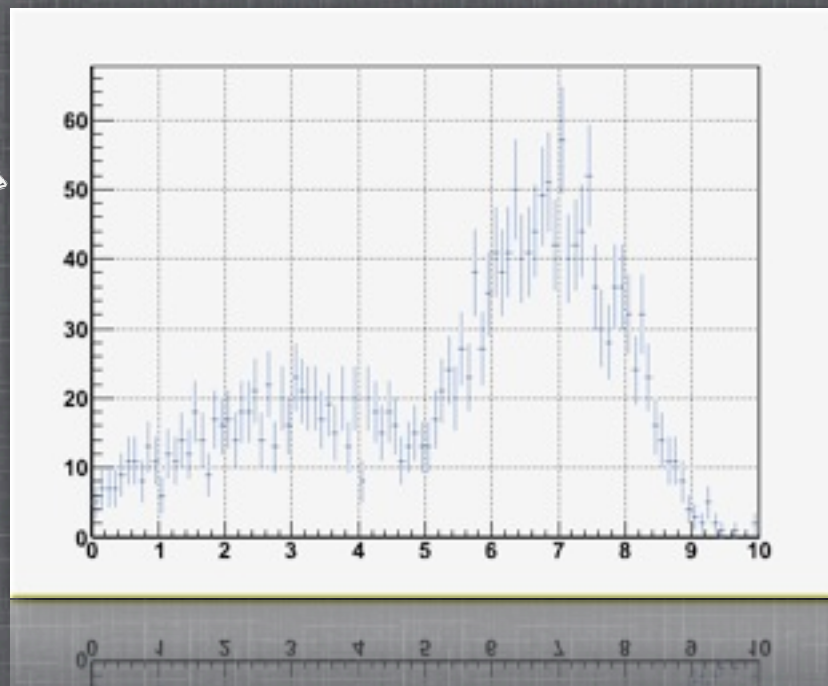
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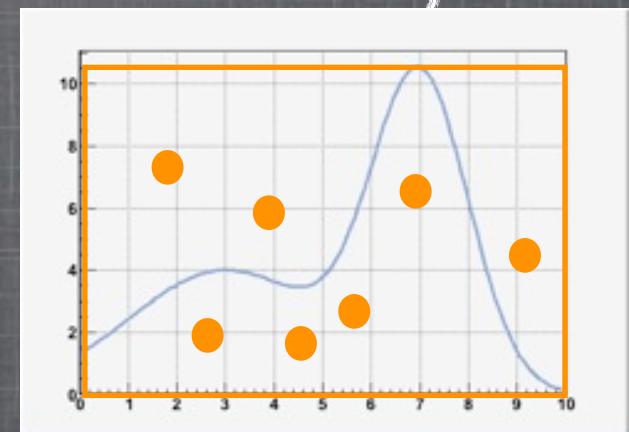


$$F(x) = \frac{\int^x f(u) du}{\int f(u) du}$$



Accept - Reject Method

(x_i, y_i) uniform in \square



accept x_i if $y_i < f(x_i)$
 $\rightarrow x_i$ ' $f(x)$ distributed' !

What is It?

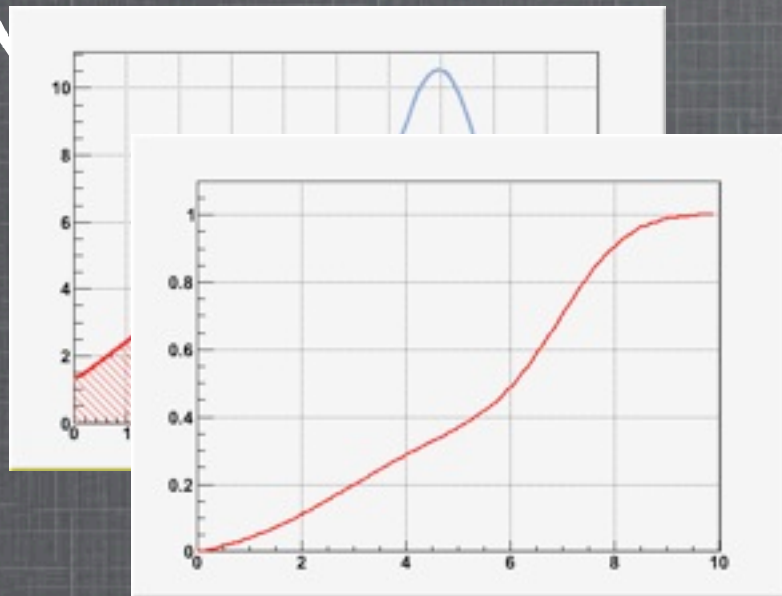
Monte Carlo method ...

- if $f(x)$ is a probability density function -

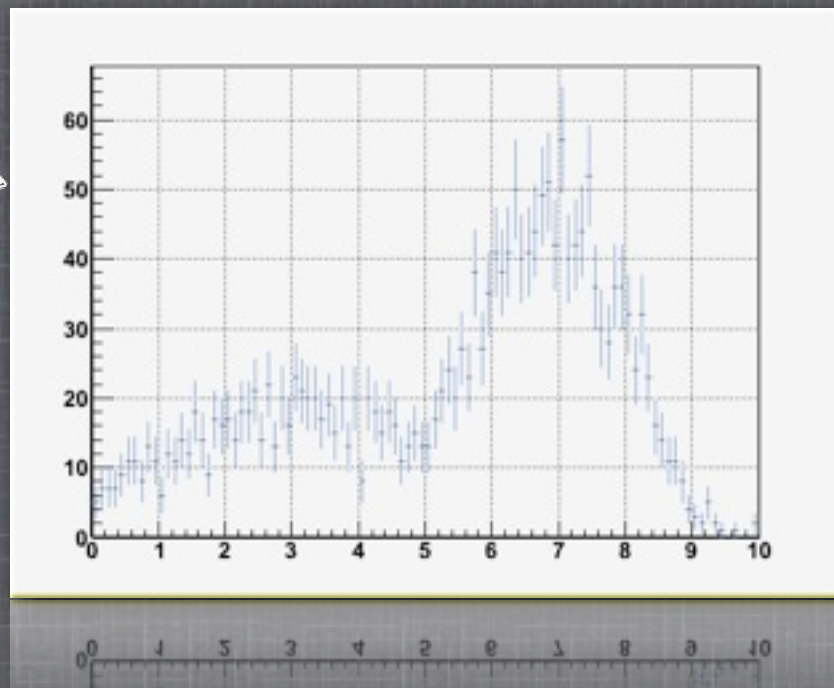
Inverse Method

x uniform in $[0,1[\Rightarrow F^{-1}(x)$ is ' $f(x)$ distributed'

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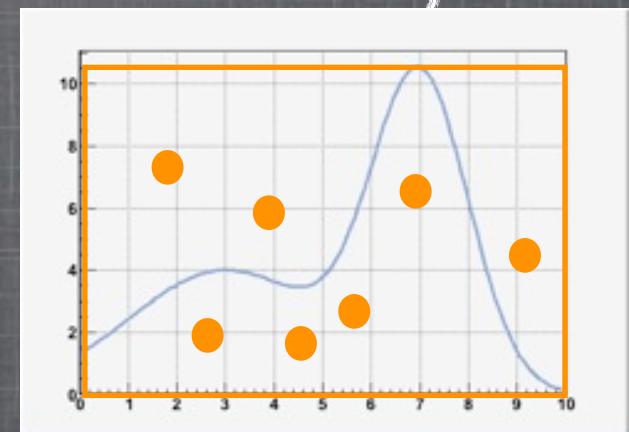


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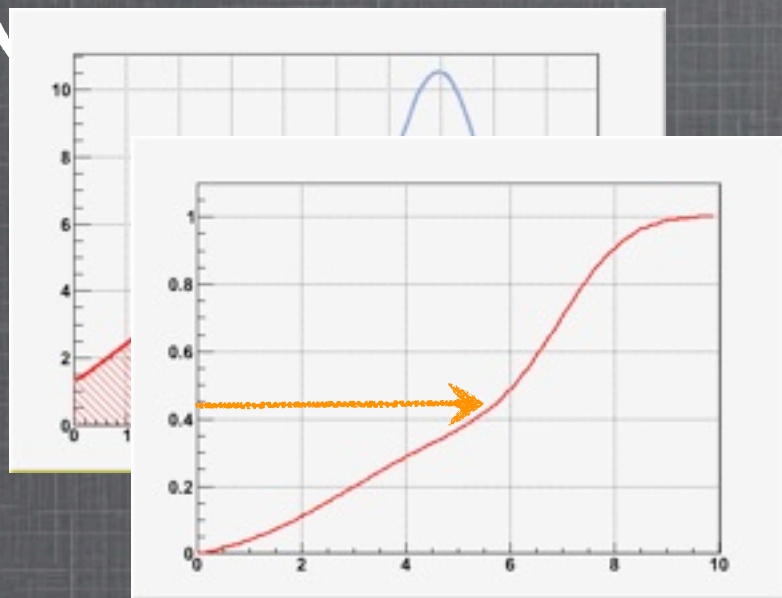
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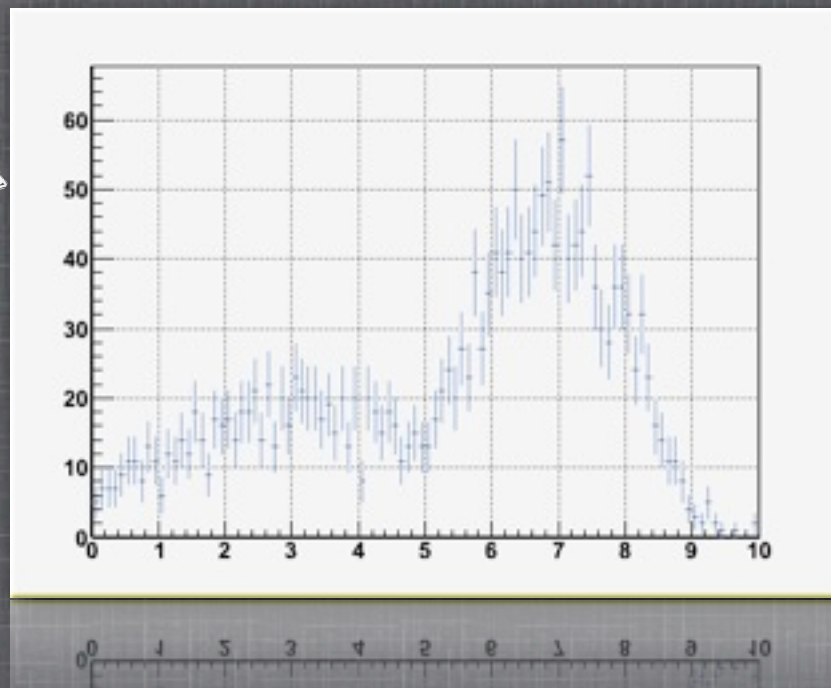
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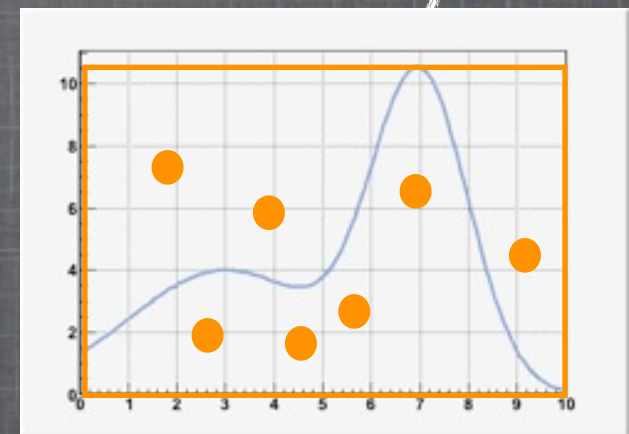


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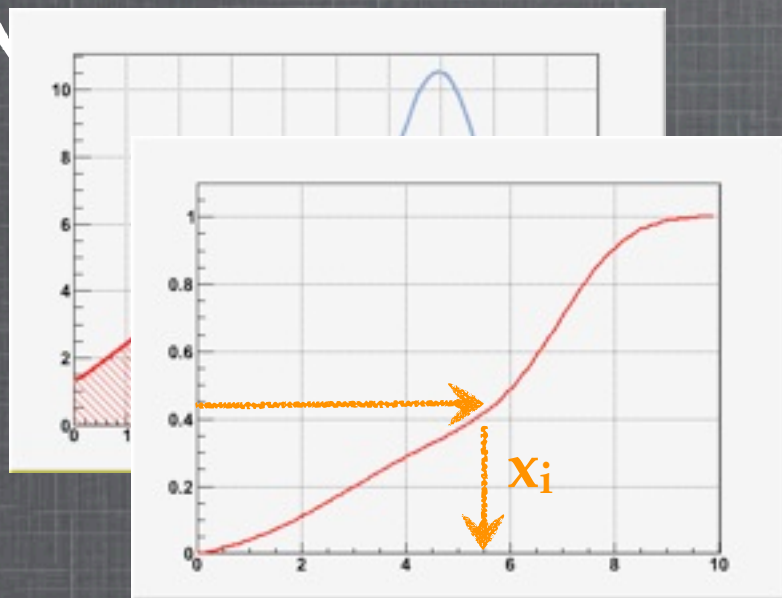
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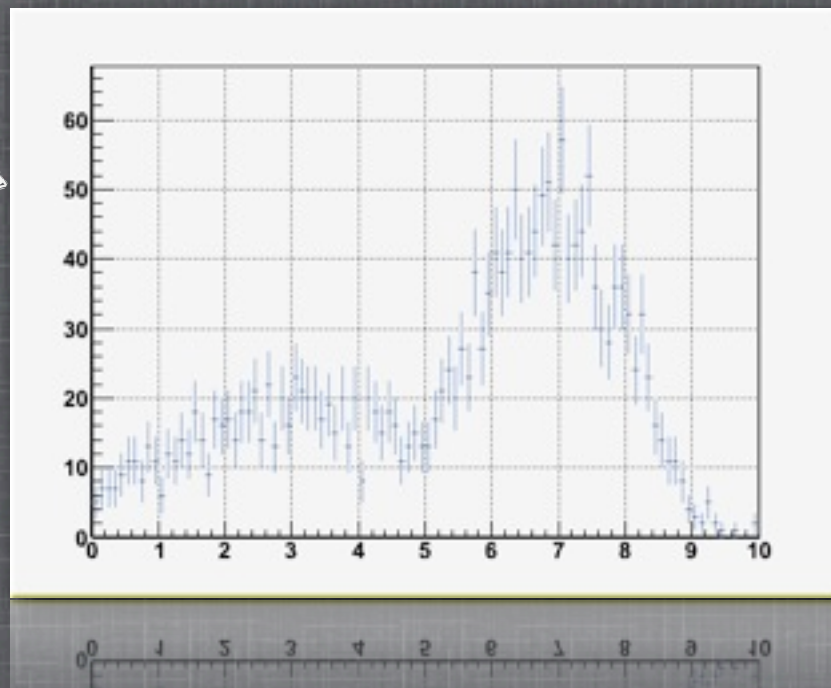
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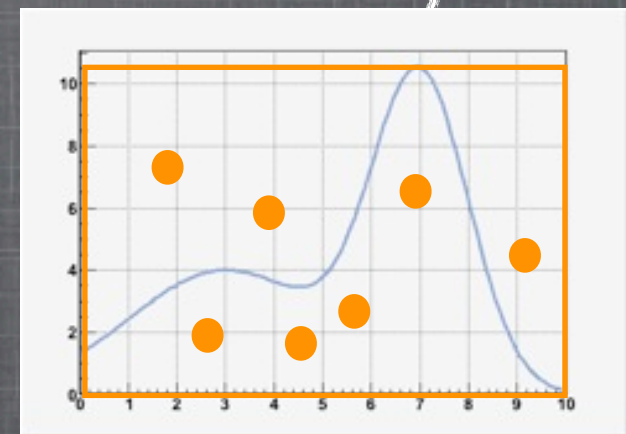


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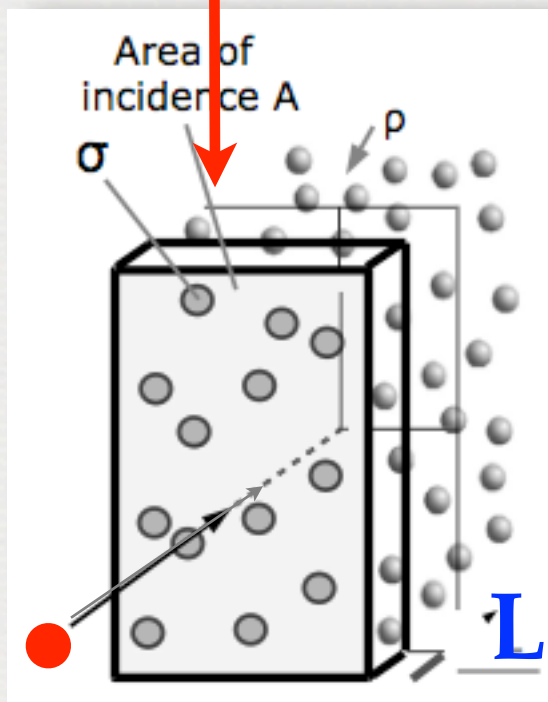


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What is It?

Monte Carlo method ...

One **particle** goes through **many others** (stopped)



- ➔ one cannot know where they are
- ➔ even if, it would cost a lot of computing power
- ➔ Quantum mechanism: interactions are probabilistic !
- ➔ statistical methods ...

Hypothesis :

Nuclei are uniformly distributed

Probability for the **particle** to travel undisturbed for a distance **L** ?

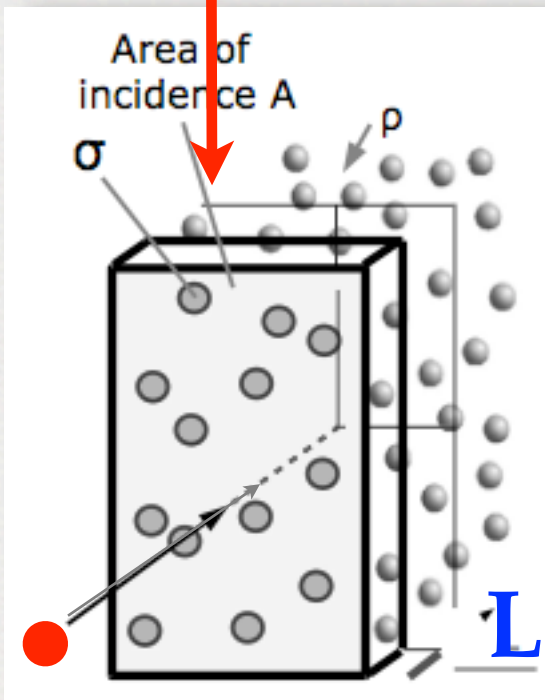
$$I_0(L) = \frac{\text{Number of particles reaching } L \text{ without 'interaction'}}{\text{Number of particles shot}}$$

frequentist's approach

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frequentist's approach

➡ scattering
➡ decay

What is It?

Monte Carlo method ...

After playing a bit $\Rightarrow I_{\odot}(L) = \exp(-\rho.L.\sigma)$

ρ macroscopic density of matters

σ microscopic cross section of the interaction process

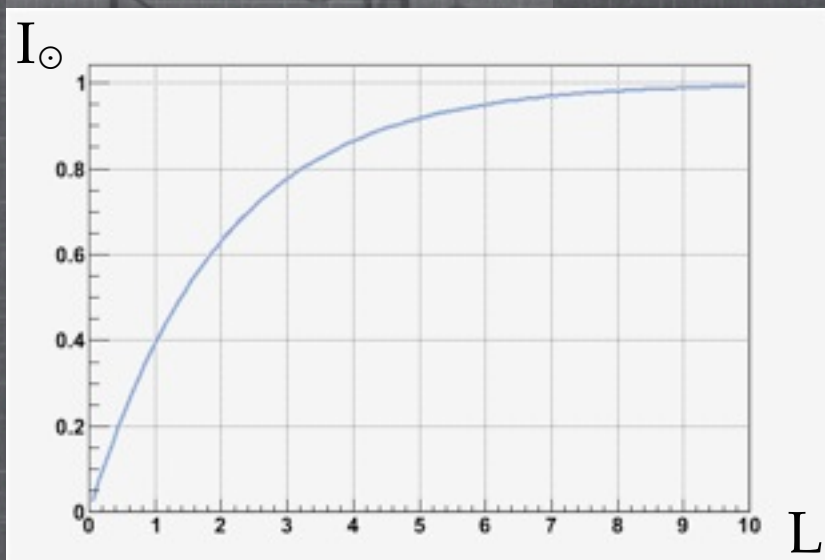
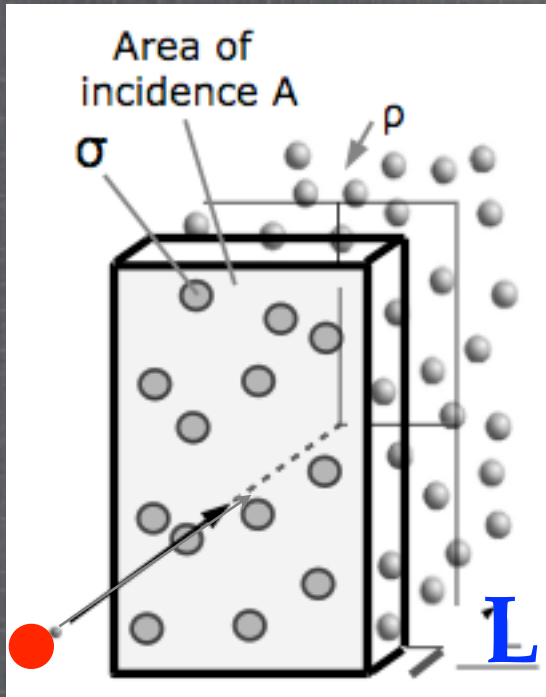
σ (type particle, energy, ...) - ex : $\sigma = \pi r^2$

\rightarrow it relies on models, measurements (database)

Probability to have an interaction at L :

$$\Rightarrow I_{\odot}(L) = 1 - I_{\ominus}(L) = 1 - \exp(-L/\lambda)$$

where λ (type ...) is the mean free path length



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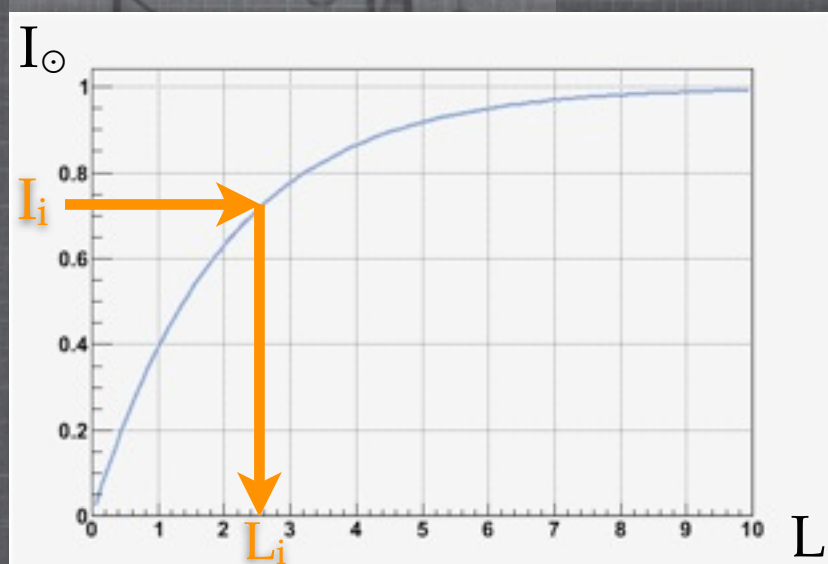
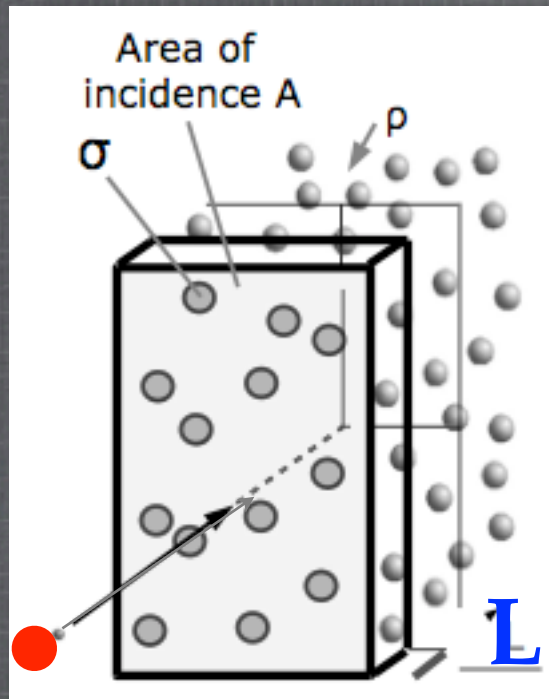
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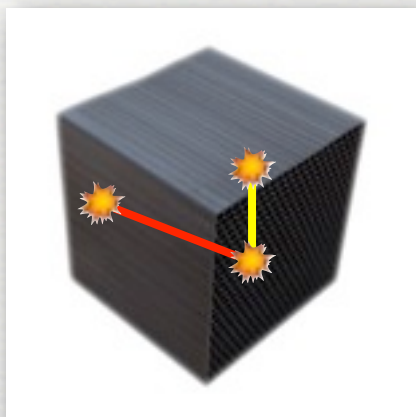
to simulate one shot,
select randomly $I_i \rightarrow L_i$

What is It?

Monte Carlo method ...

General case: competition between several processes iI

iI_0 the probability of having an interaction at distance L



What is It?

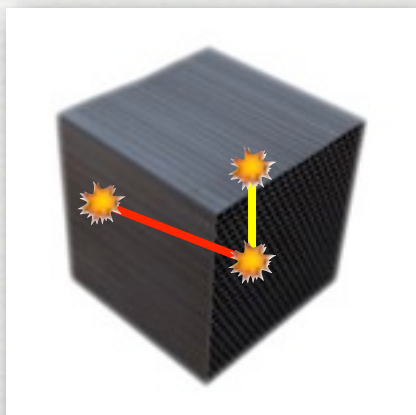
Monte Carlo method ...

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iI_0 the probability of having an interaction at distance L

- start values for incident particle
- get value for Q, σ
- sample L_i from iI_0
- smallest L_s selects the process sI
- transport particle undisturbed by L_s
- simulate **interaction**

1I 
 2I 
 \vdots
 nI 



What is It?

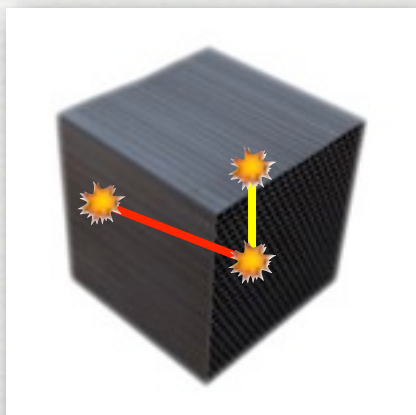
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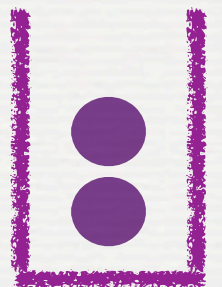
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secondary particles



What is It?

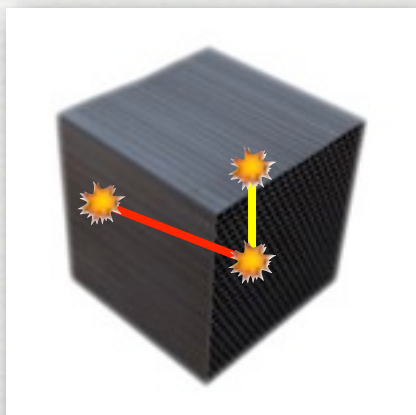
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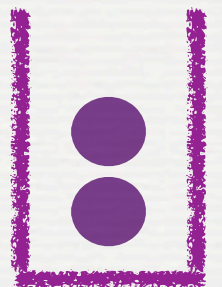
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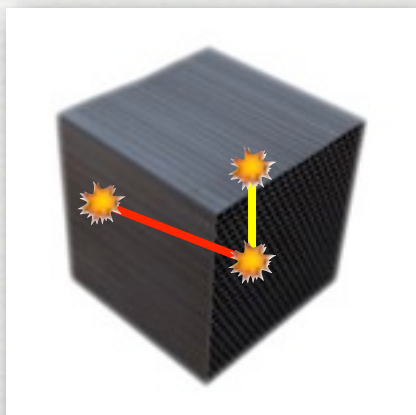
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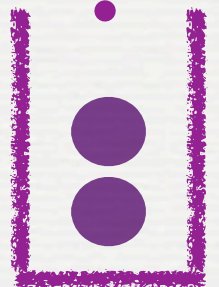
iI_0 the probability of having an interaction at distance L

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\rightarrow secondary particles



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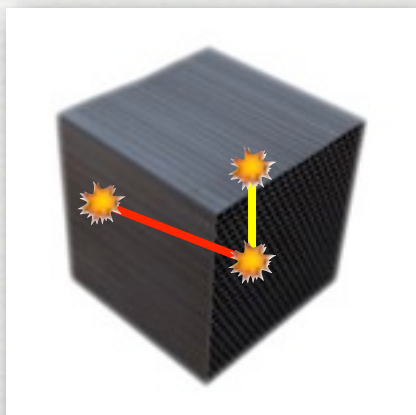
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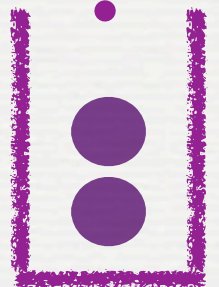
Core of the Monte Carlo Method !

- start values for incident particle $\leftarrow \bullet$
- get value for ϱ, σ
- sample L_i from iI_0
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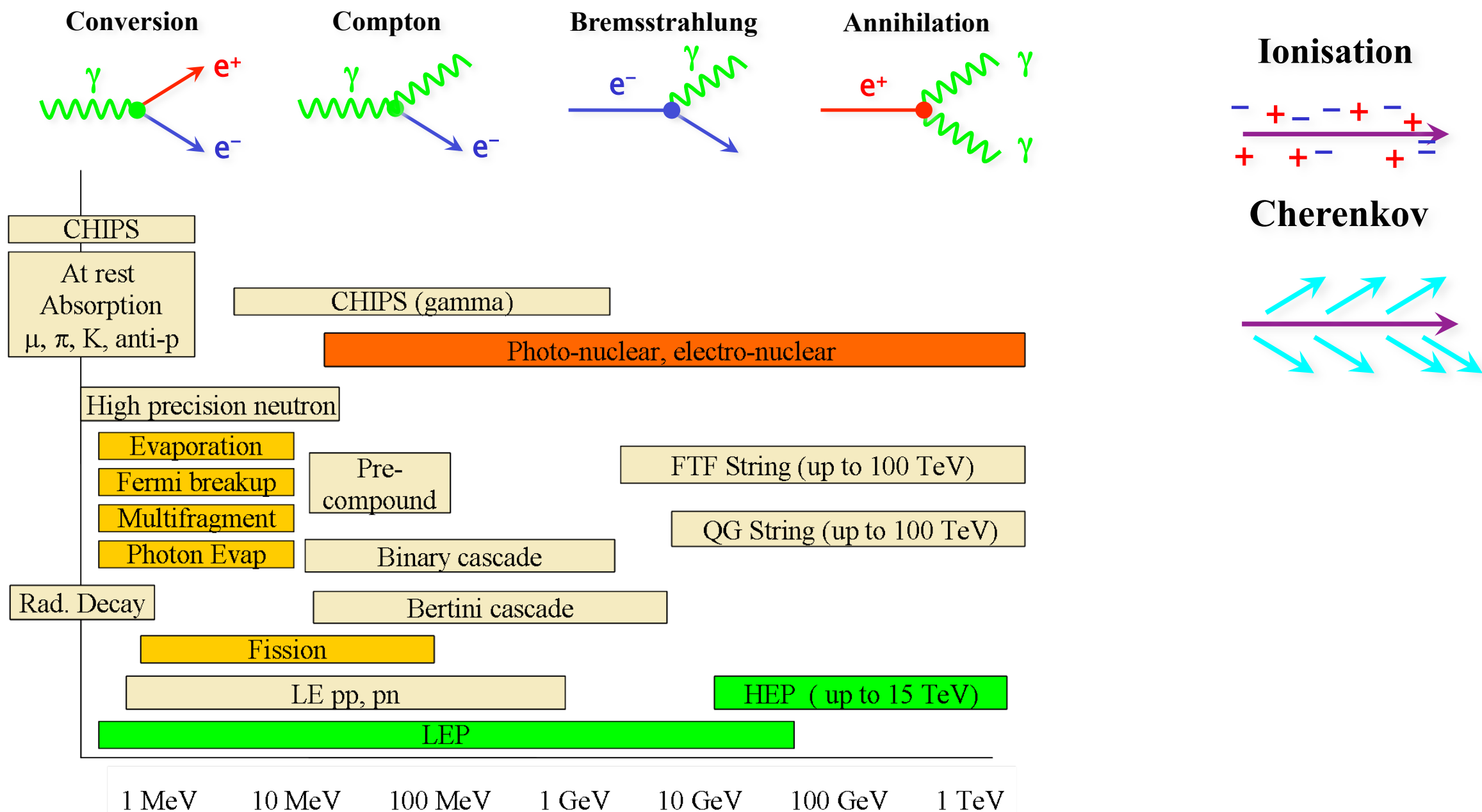


 secondary particles



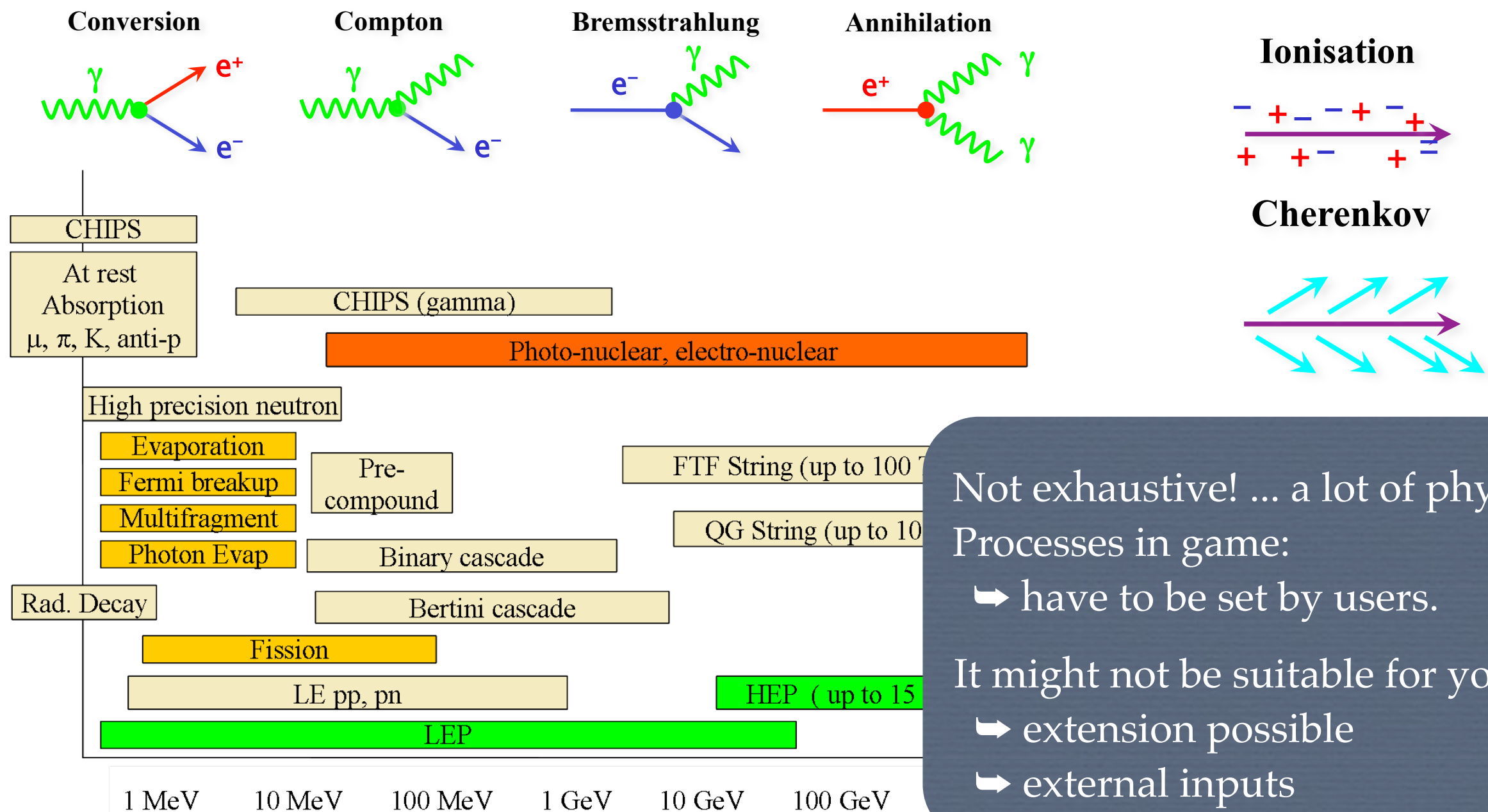
What is It? A quick overview of processes in G4

Electromagnetic, hadronic, optical, transport, decay ...
(based on models and / or databases-measurements ... expandable !)



What is It? A quick overview of processes in G4

Electromagnetic, hadronic, optical, transport, decay ...
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Not exhaustive! ... a lot of physics!
Processes in game:
➔ have to be set by users.

It might not be suitable for you !
➔ extension possible
➔ external inputs



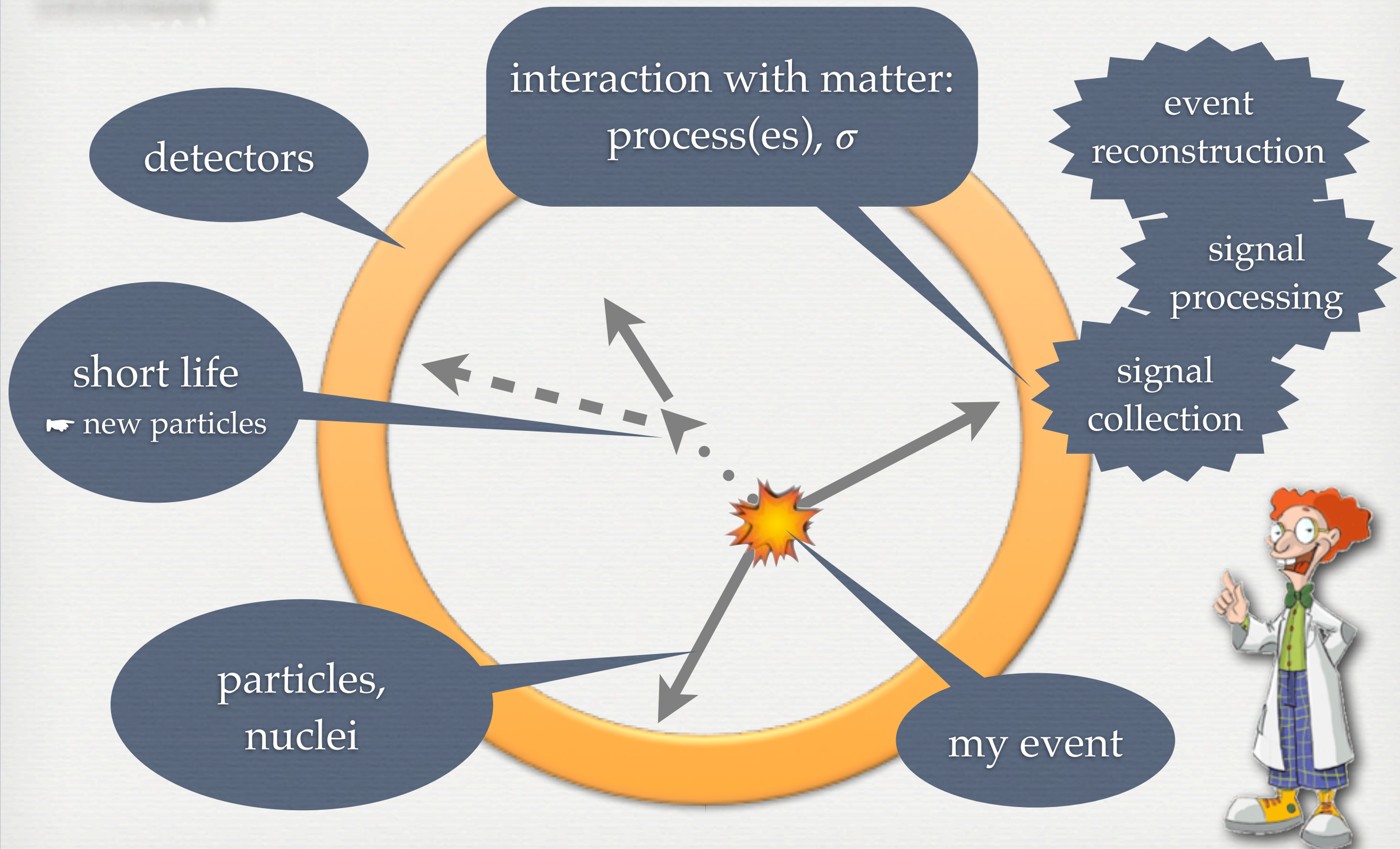
Some general statements

Monte Carlo into the *game*

Geant4 some vocabulary

The Geant4 machine

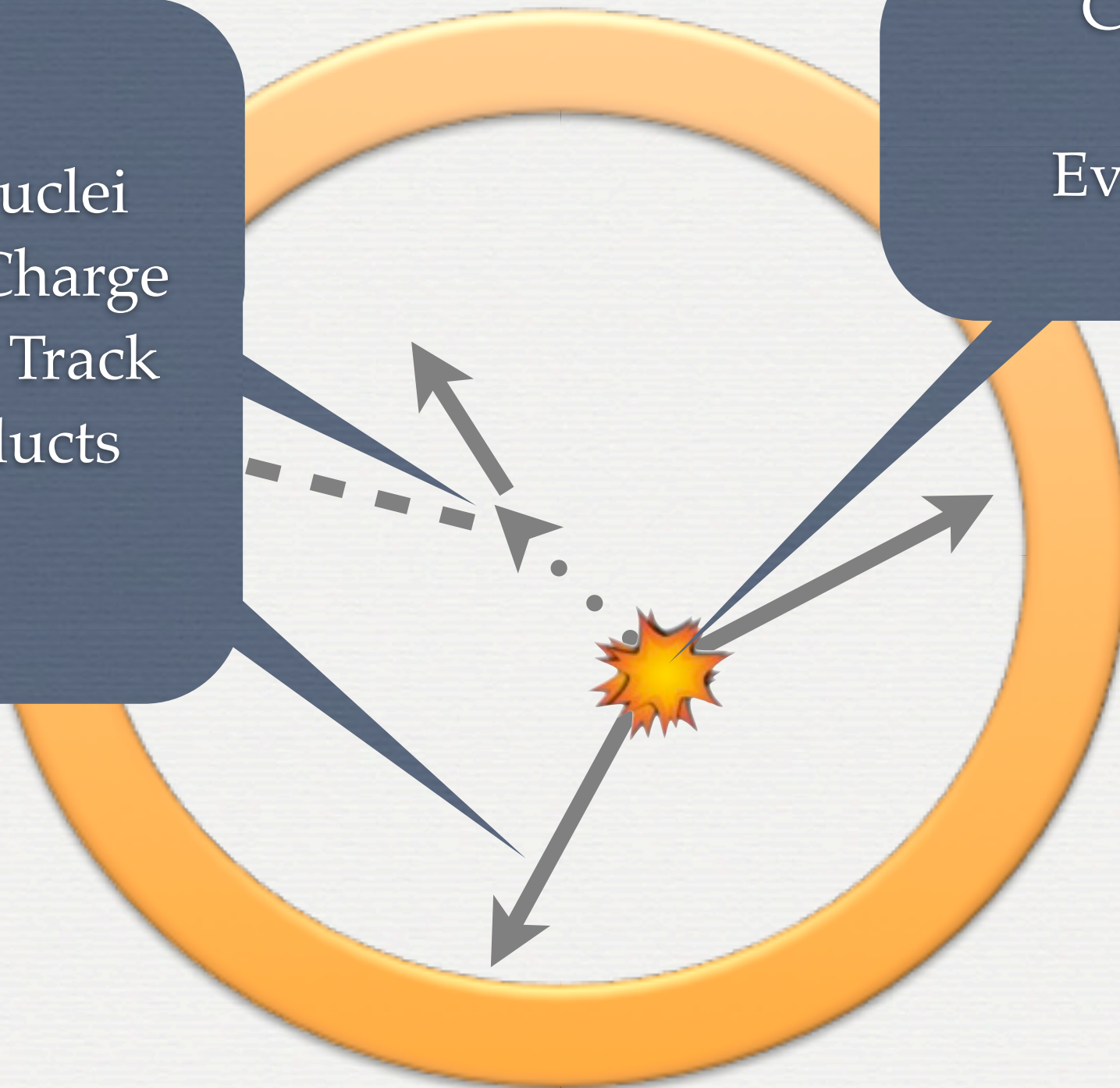
What is It? the world to be modeled



What is It? the world to be modeled

Particles, Nuclei
Mass, Spin, Charge
Momentum, Track
Decay products
...

Collisions
Vertex
Events, Run
...

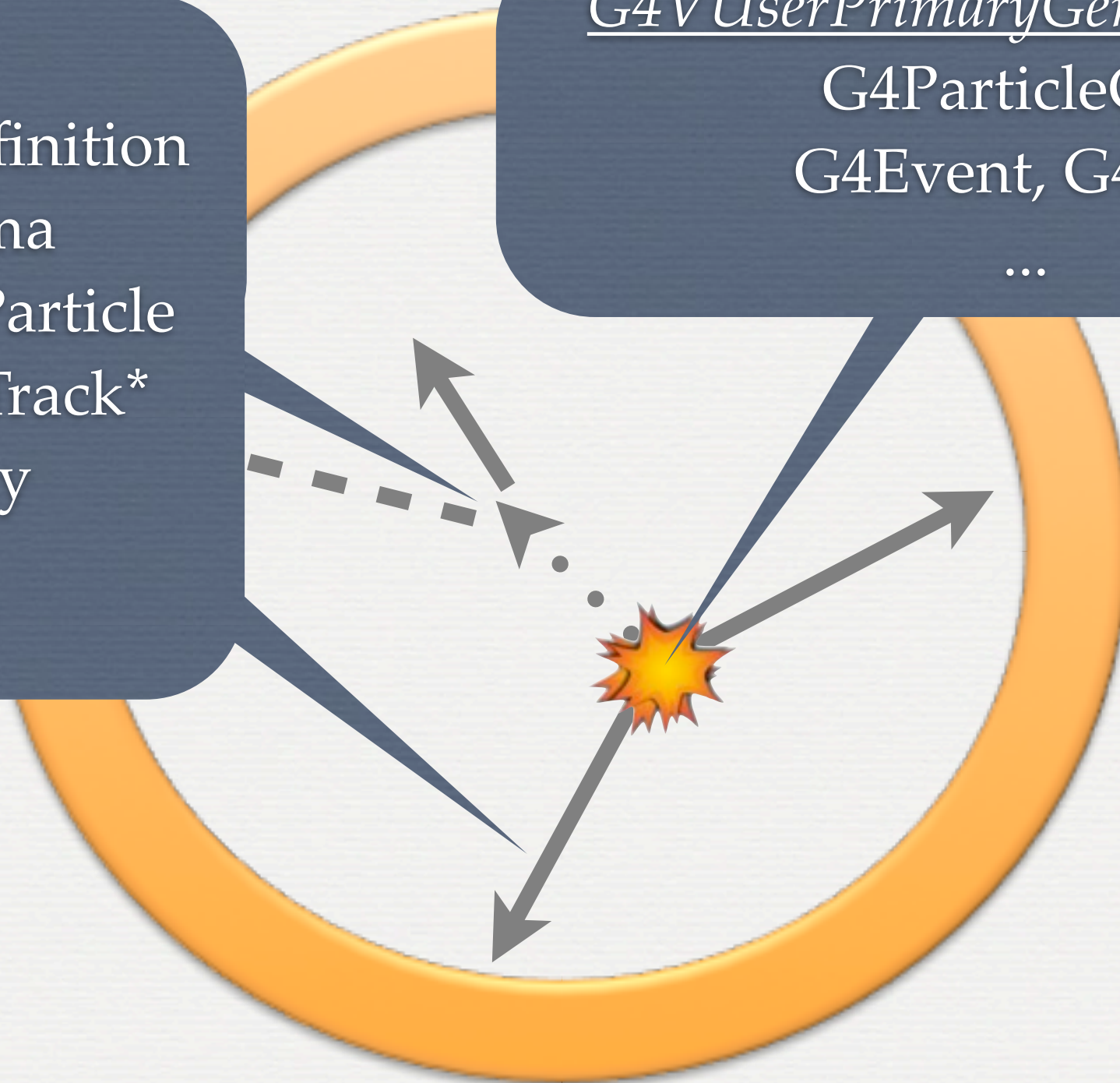


What is It? the GEANT4 [G4] world

G4ParticleDefinition
G4Gamma
G4DynamicParticle
G4Step, G4Track*
G4Decay
...

G4VUserPrimaryGeneratorAction

G4ParticleGun
G4Event, G4Run
...

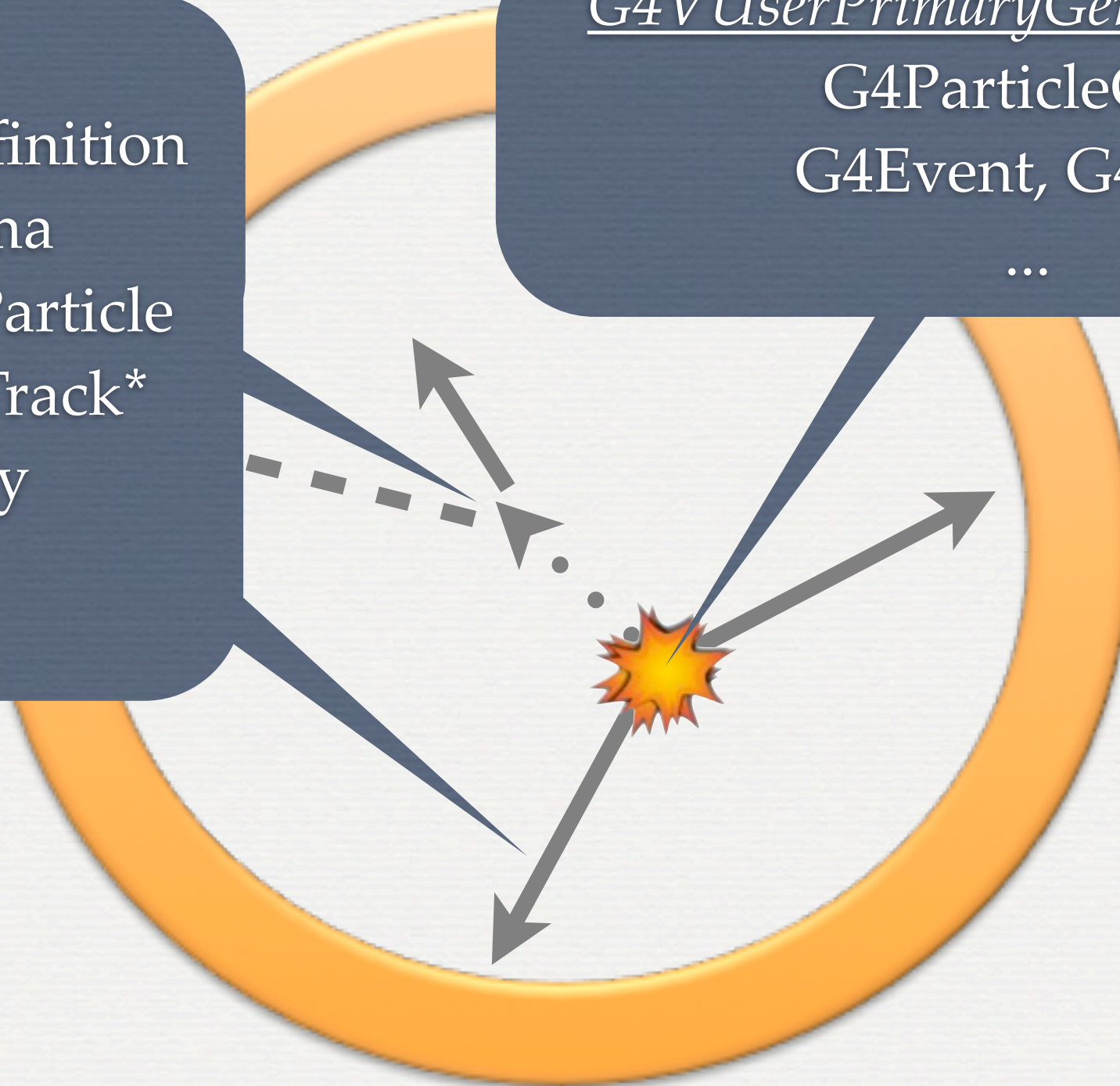


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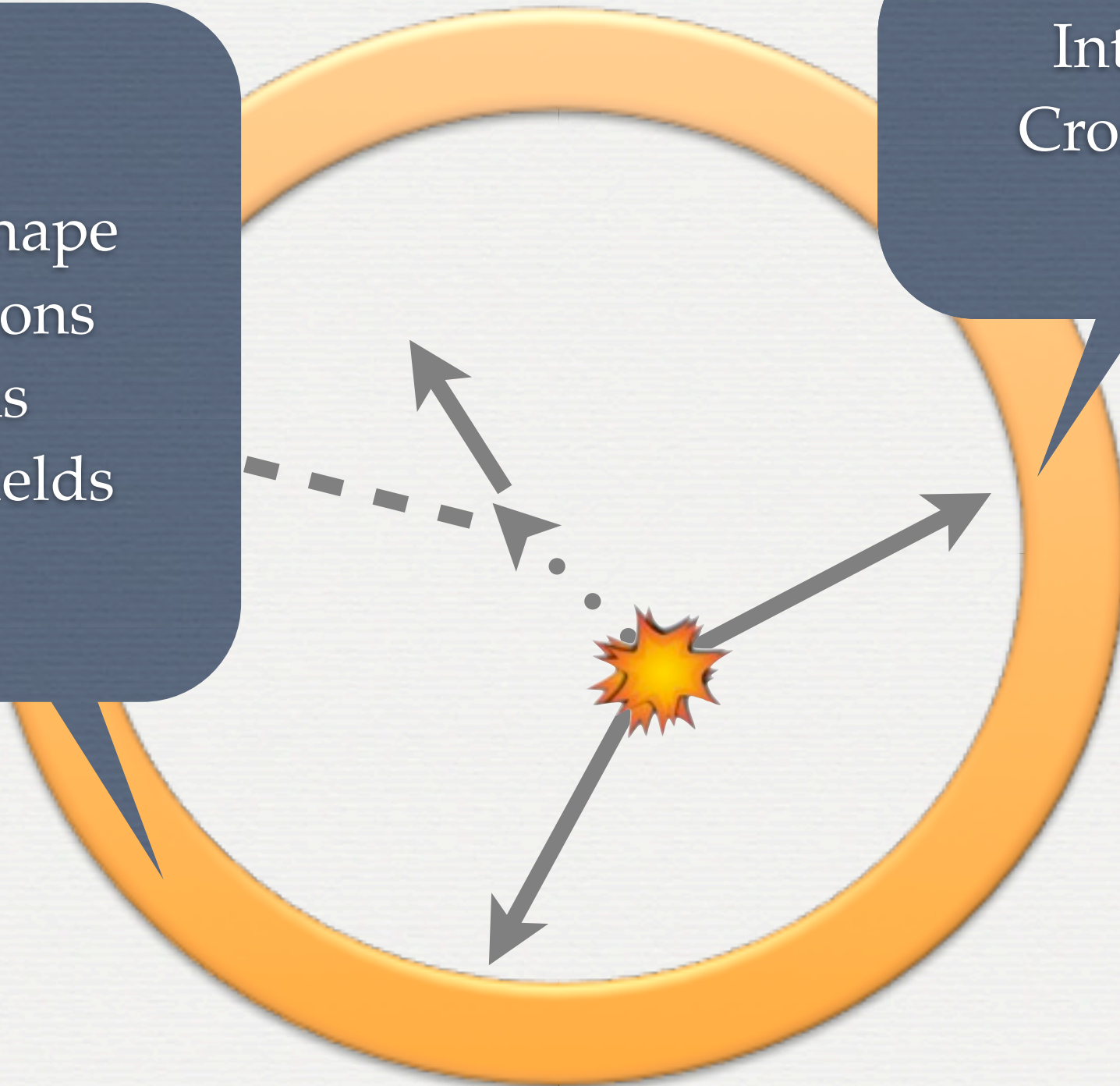
* a G4Track is not a collection of G4Step but a snapshot of a particle within its environment



What is It? the world to be modeled

Setup
Material, Shape
Compositions
Positions
Magnetic fields
...

Interactions
Cross Sections
...



What is It? the GEANT4 [G4] world

G4VUserDetectorConstruction

G4Material, G4Solid

G4LogicalVolume,

G4VPhysicalVolume

G4ThreeVector, G4RotationMatrix

G4Field

...

G4VUserPhysicsList

G4VProcess

...



What is It? the world to be modeled

He is:
a designer
a builder
a manager
an analyzer
...

Readout

Hits

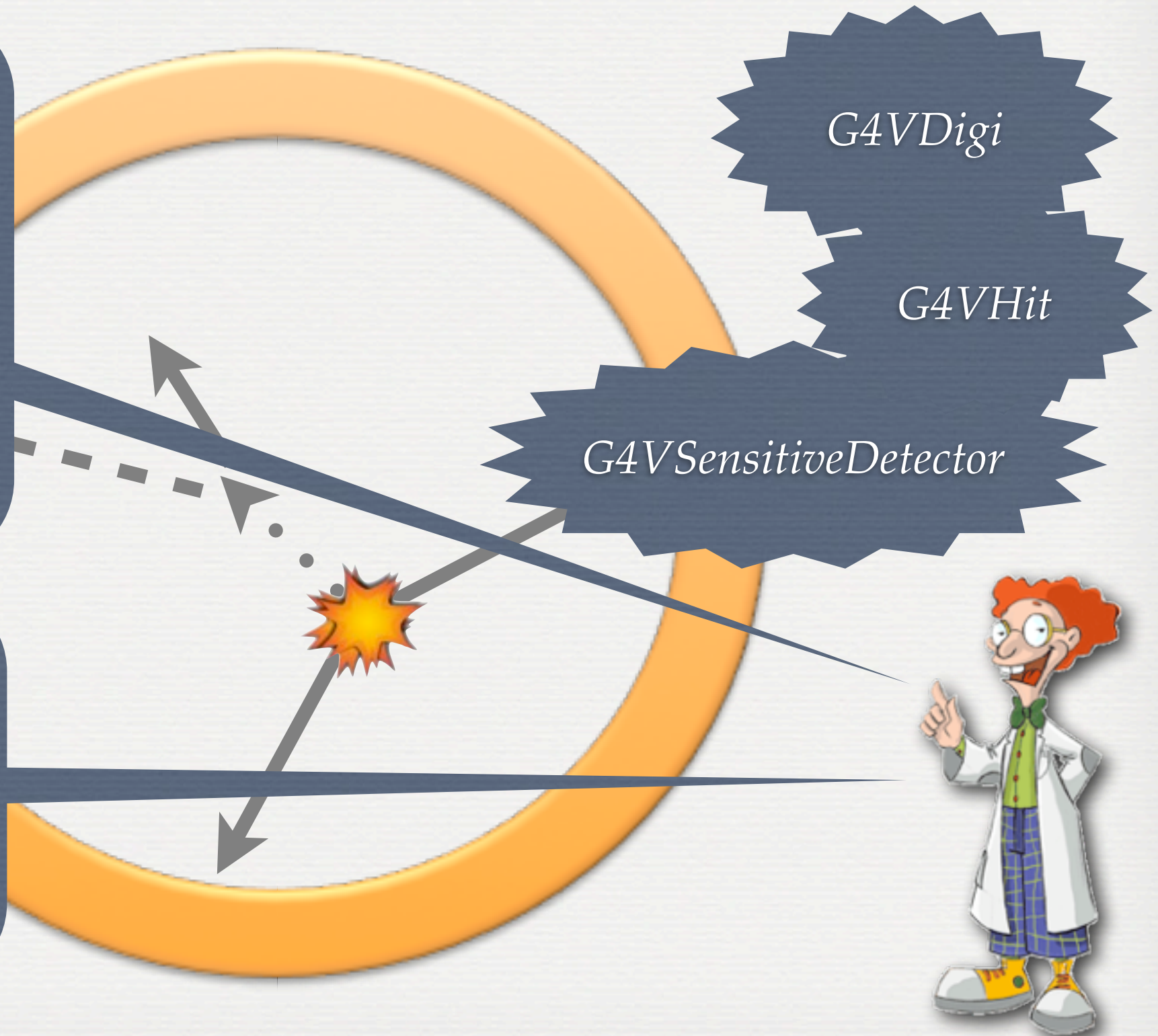
Sensitive
part



What is It? the GEANT4 [G4] world

G4 inner control
G4RunManager
G4EventManager
G4SteppingManager
G4TrackingManager
...

User's Actions
G4VUserRunAction
G4VUserEvenAction
...





Some general statements

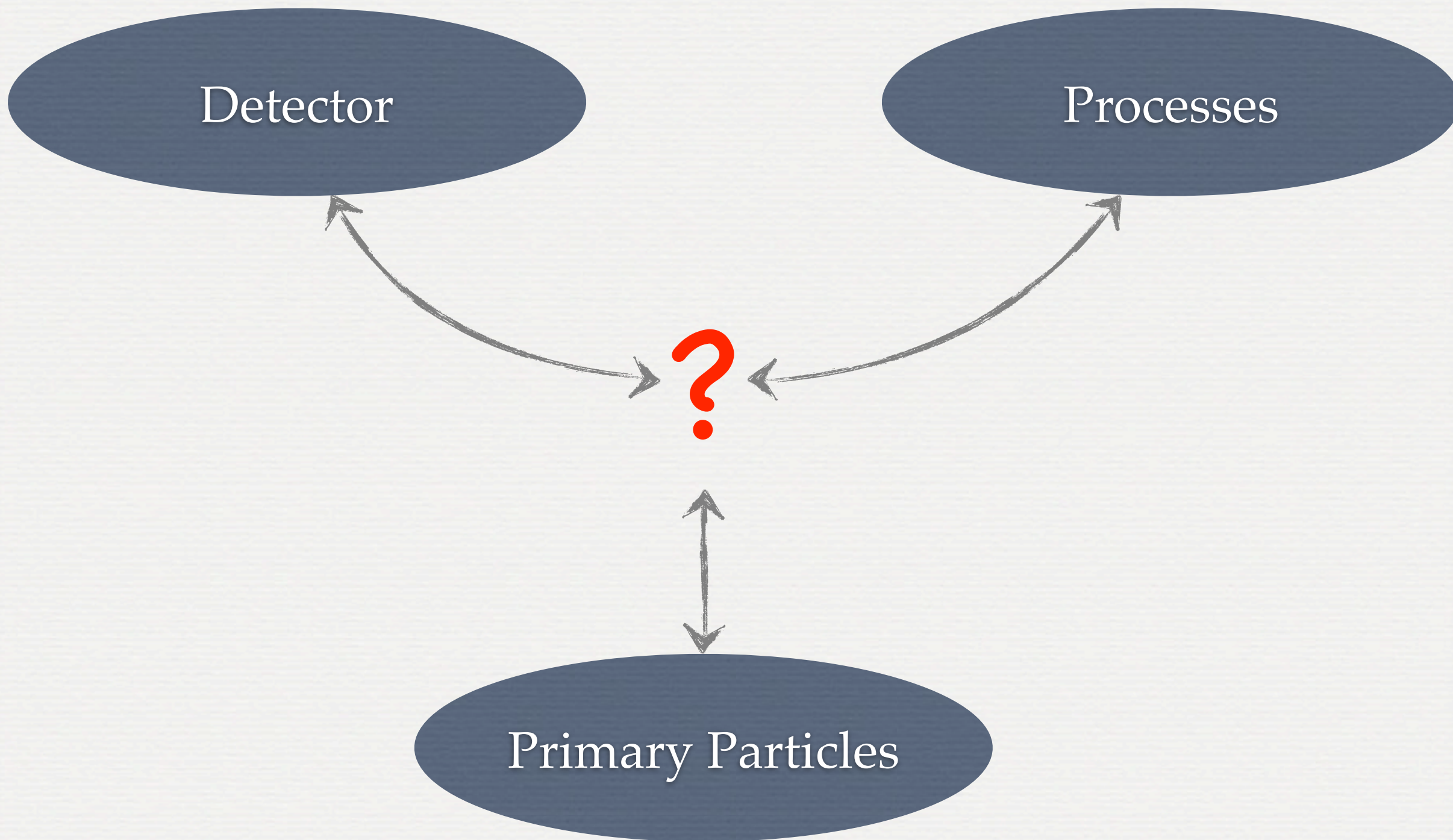
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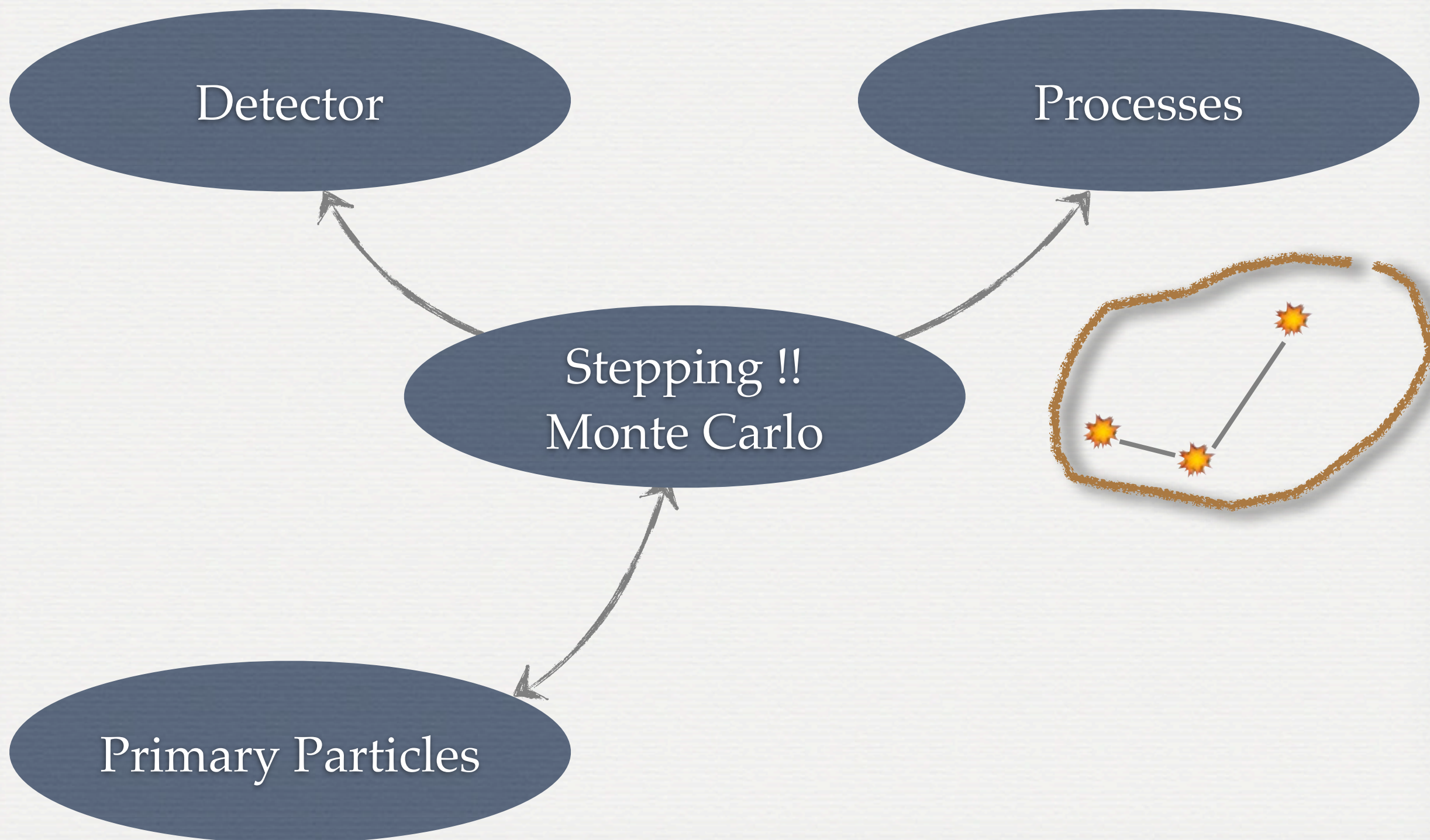
What is It?

ALL G4Things together



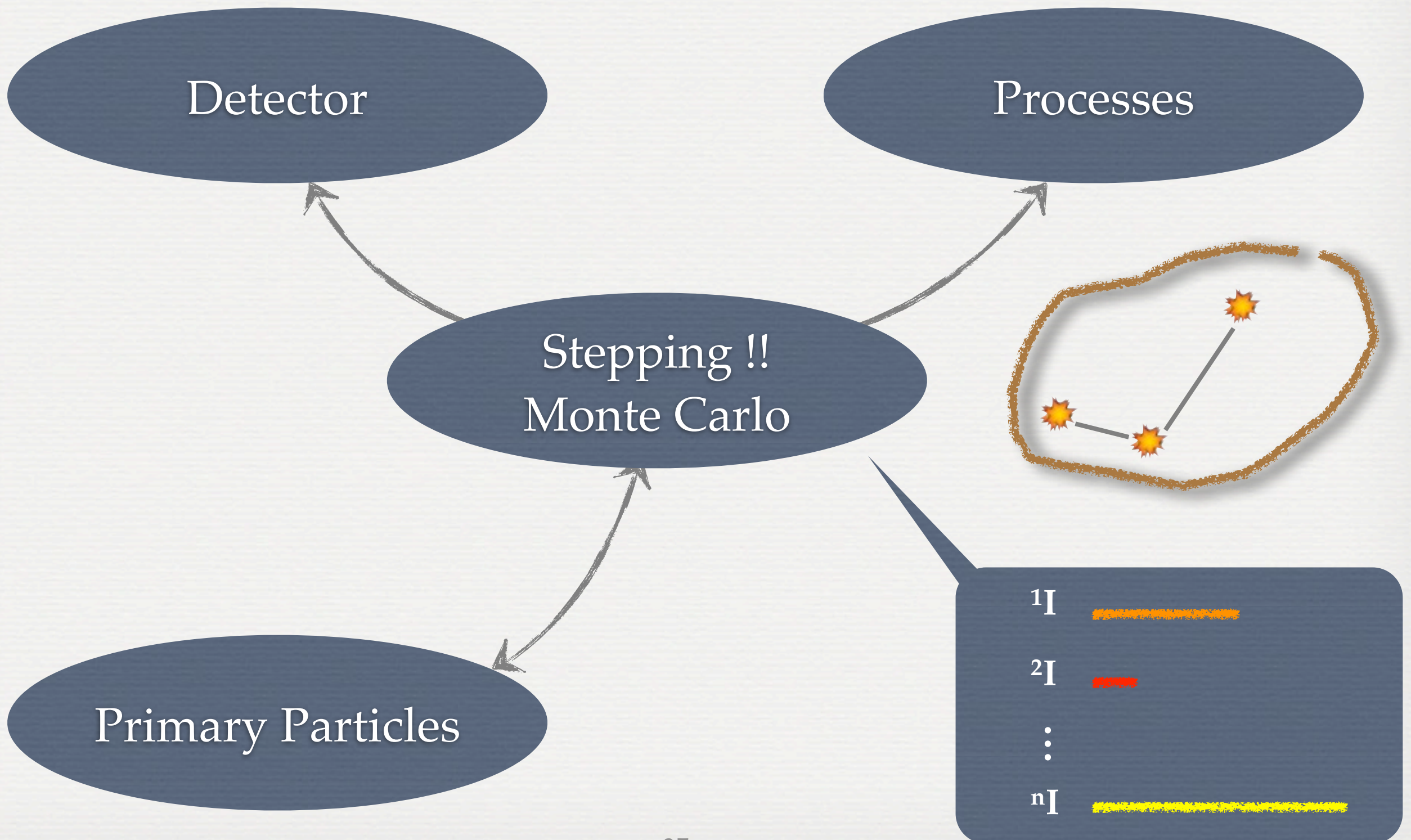
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What is It?

ALL G4 Things together



- First Phase, initialization:

- ☑ Definition of the full setup
- ☑ What particles, What processes they see
- ☑ Primary generator in action

- Then Main loop :

/run/BeamOn 10000

- Start run # 1 : conditions of simulation fixed*
- Start event # i
 - primaries randomly generated and tracked
- Stop event # i
- Stop run# 1 -

* geometry, processes

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```
public G4VUserDetectorConstruction  
{  
  ...  
}
```

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What is It? ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

Start event # i

Start **track** # j

Start **step** # k

Stop **step** # k

Stop **track** # j

Stop event # i

Stop run # 1

k Track ID

Track stack

active

waiting



What is It?

ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

Start event # i

Start track # j

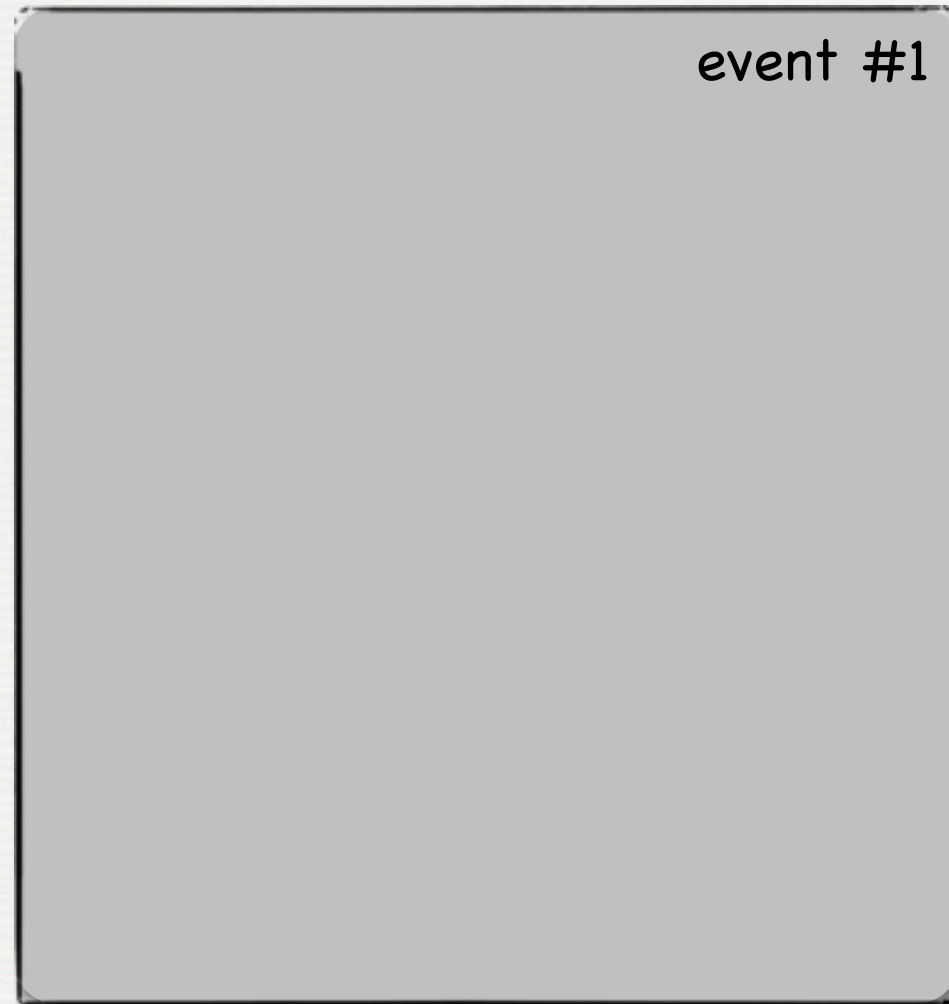
Start step # k

Stop step # k

Stop track # j

Stop event # i

Stop run # 1



 Track ID

Track stack

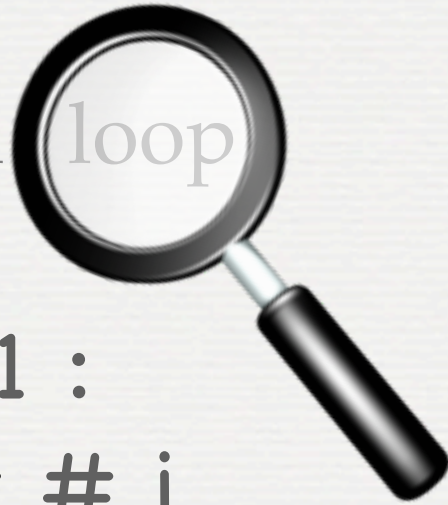
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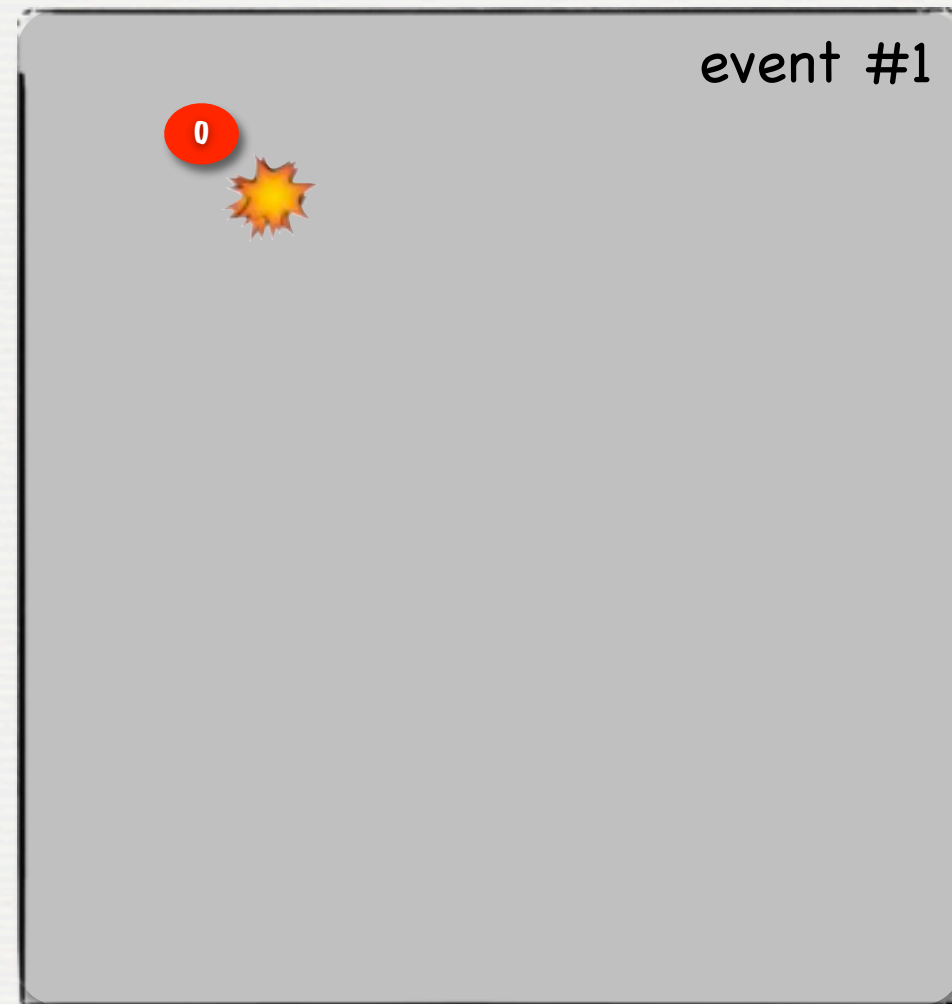
Start **step** # k

Stop **step** # k

Stop **track** # j

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Stop run # 1



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0
active

U
waiting

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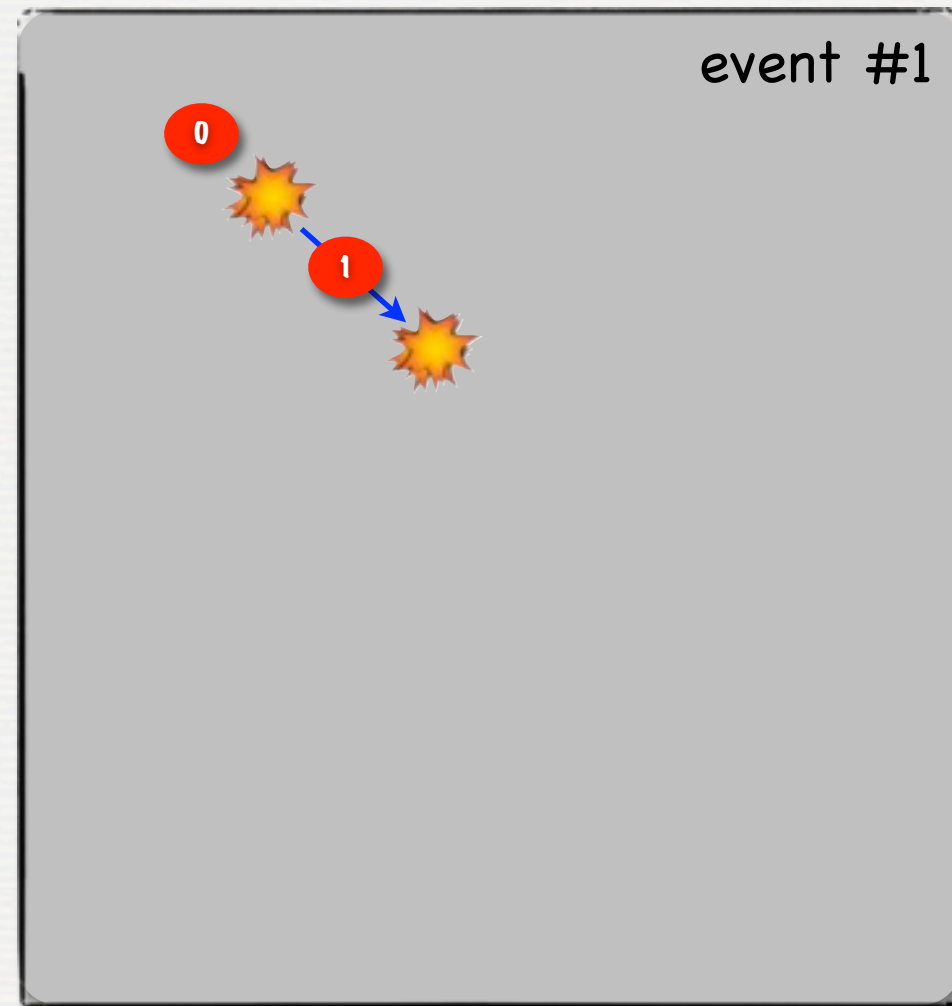
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Track stack

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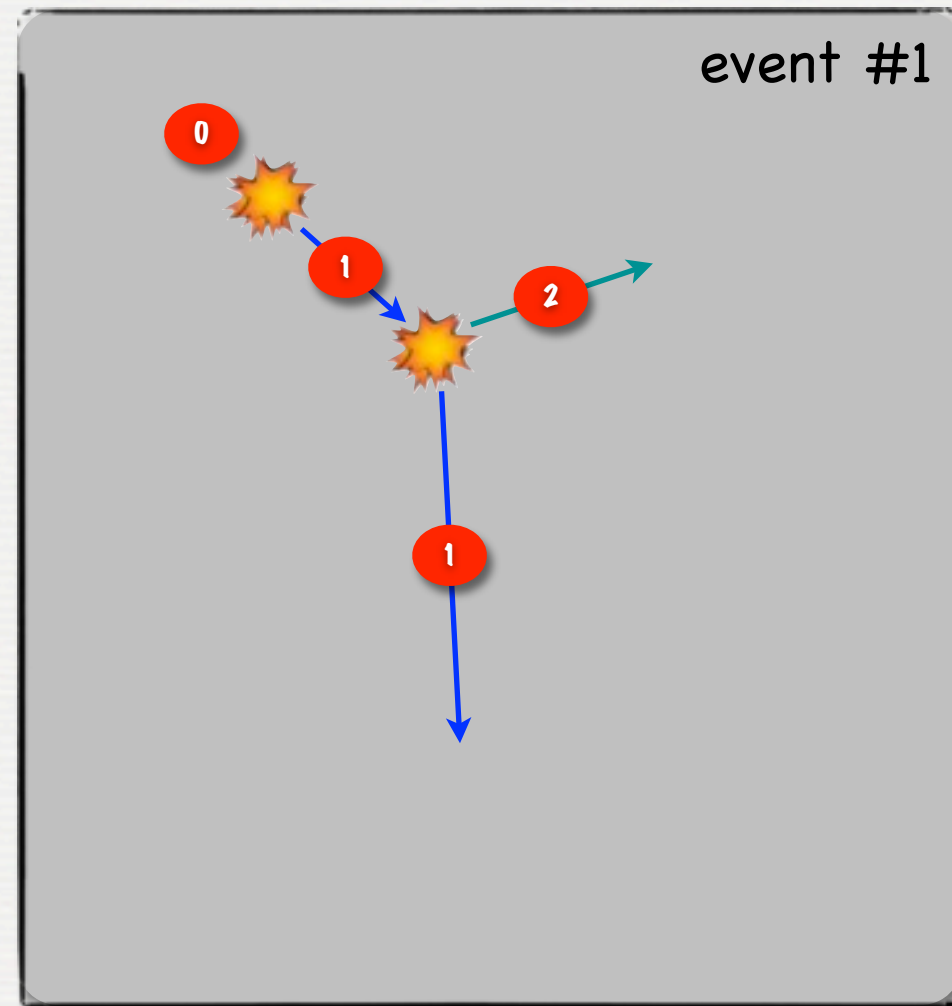
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Track stack

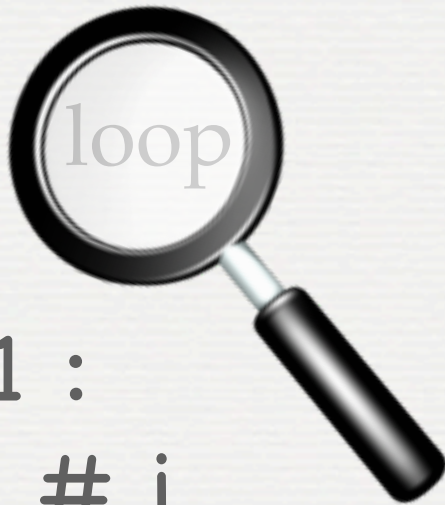
1
active

2
waiting

What is It? ALL G4Things together



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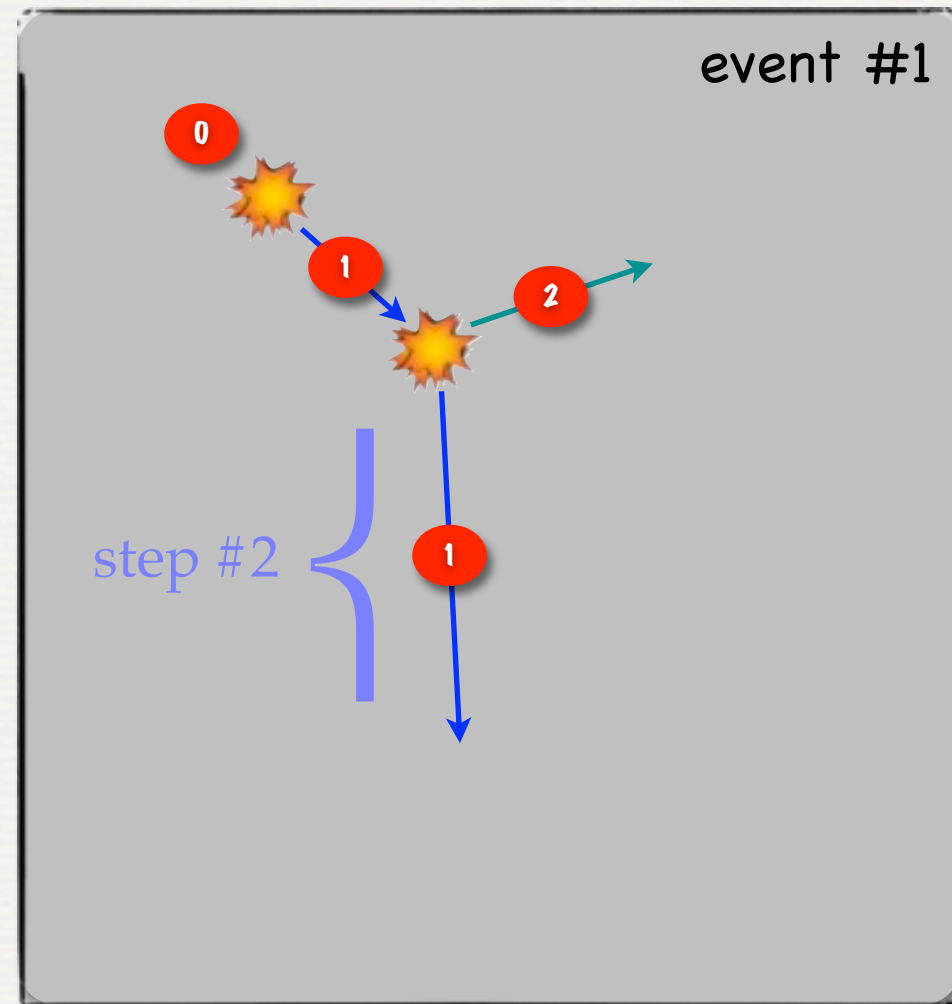
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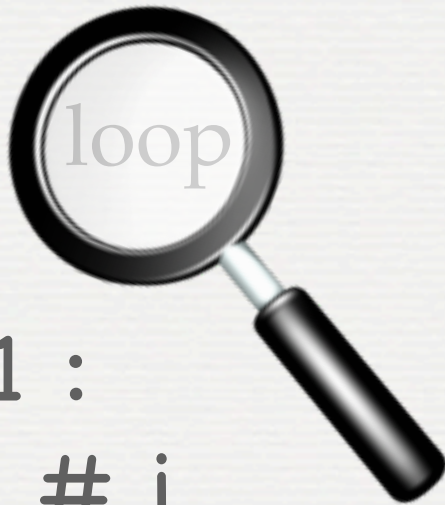
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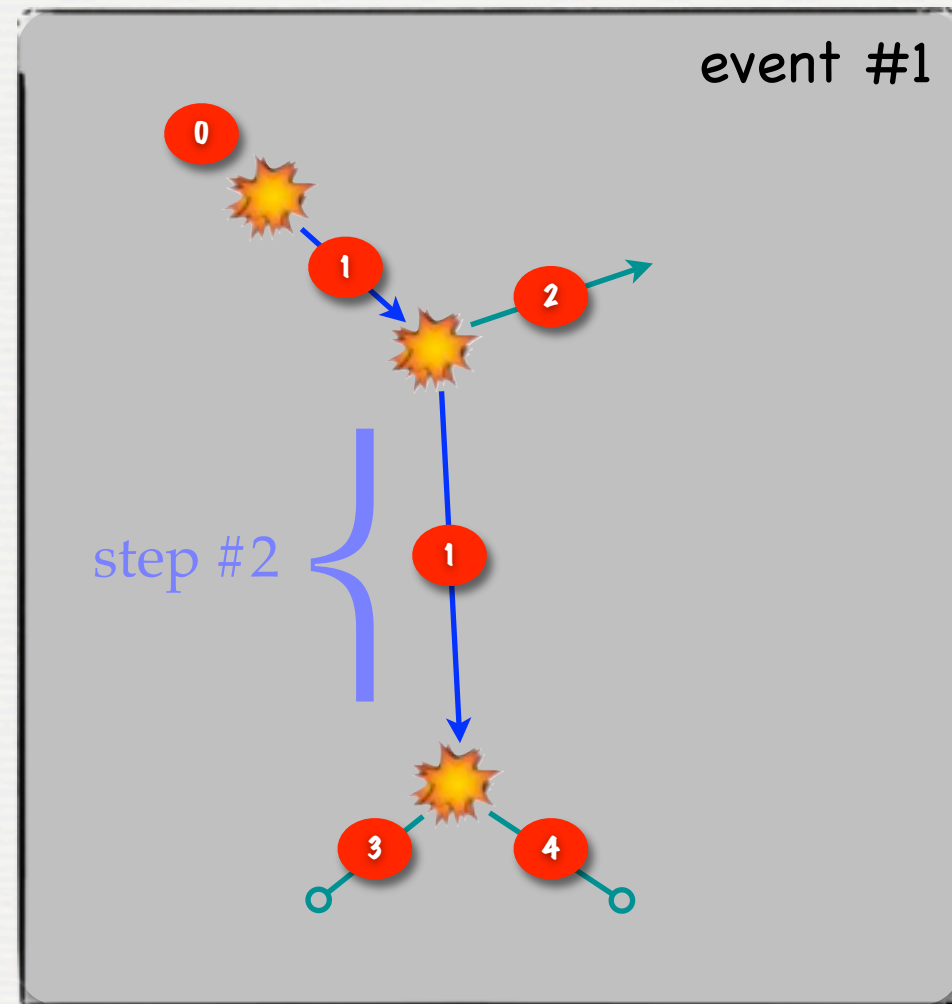
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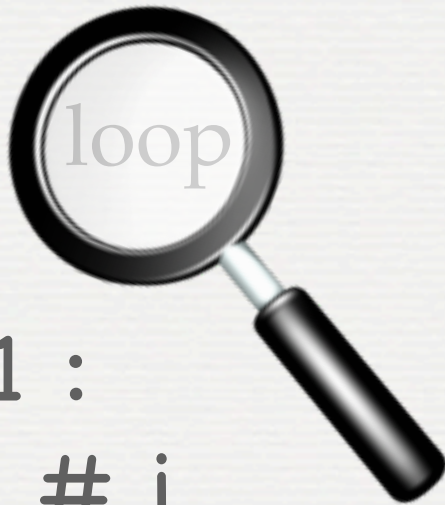
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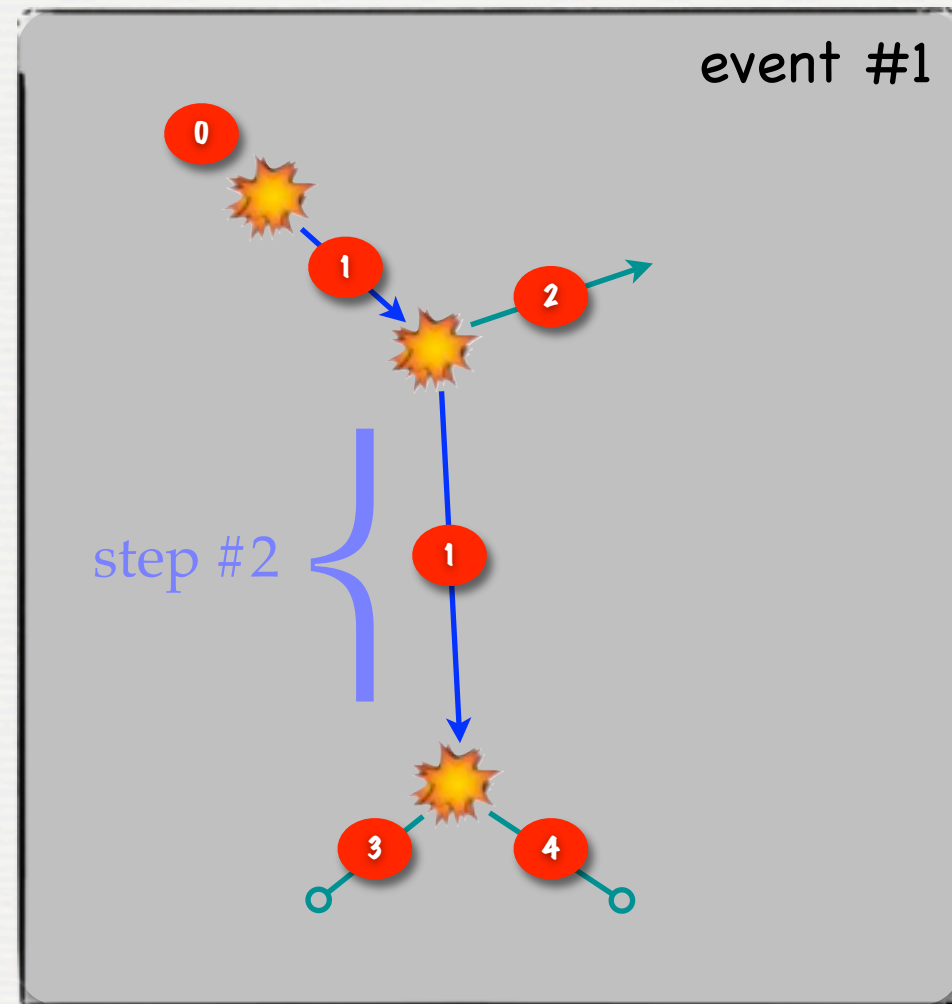
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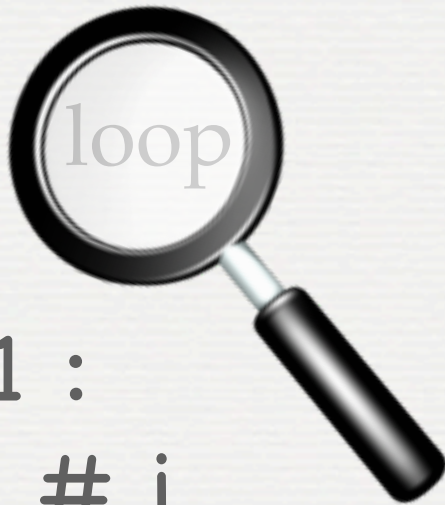
waiting



What is It? ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

Start event # i

Start **track** # j

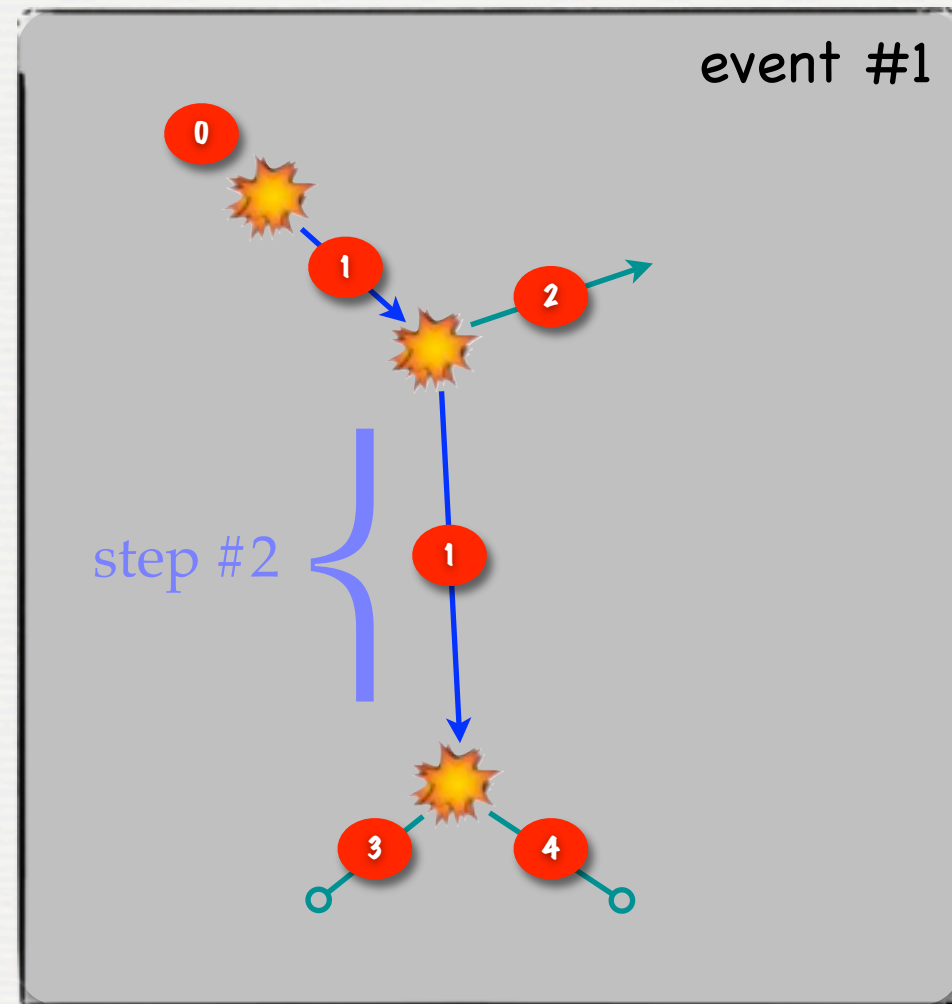
Start **step** # k

Stop **step** # k

Stop **track** # j

Stop event # i

Stop run # 1



k Track ID

Track stack

active

waiting

What is It? ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

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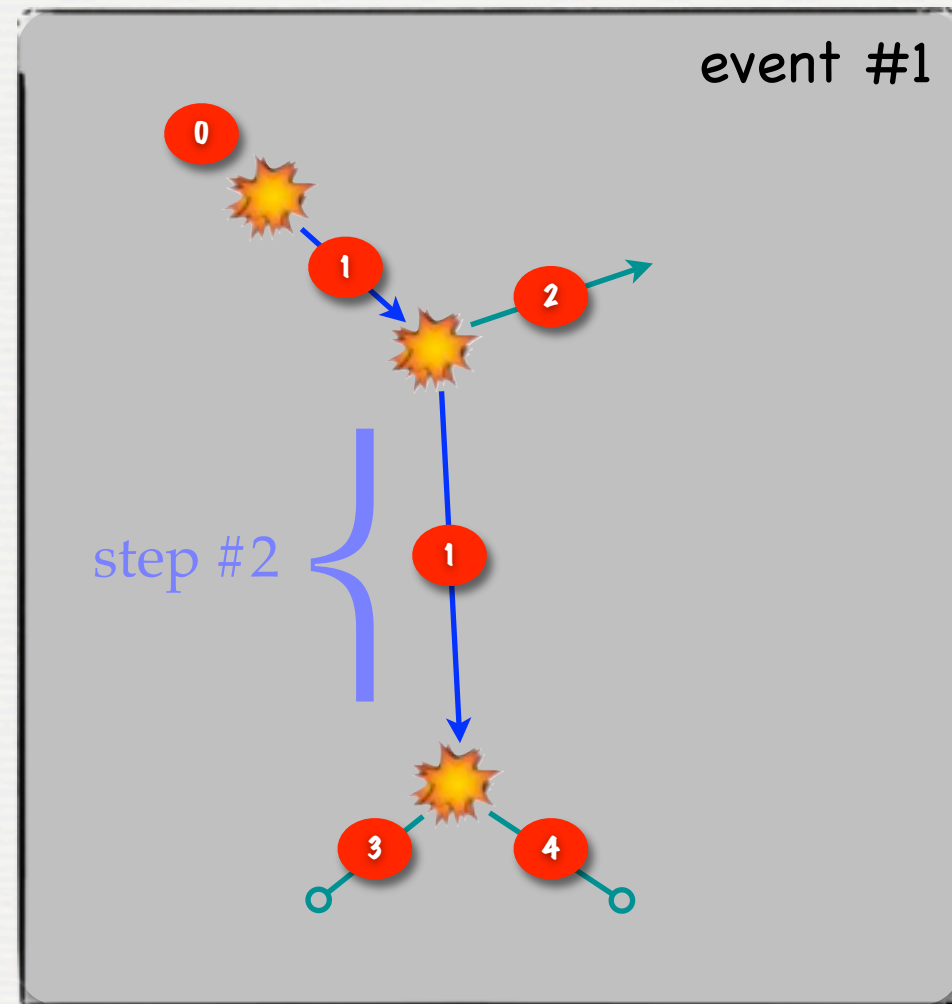
Start **step** # k

Stop **step** # k

Stop **track** # j

Stop event # i

Stop run # 1



k Track ID

Track stack

2
active

L
waiting

What is It?

ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

Start event # i

Start track # j

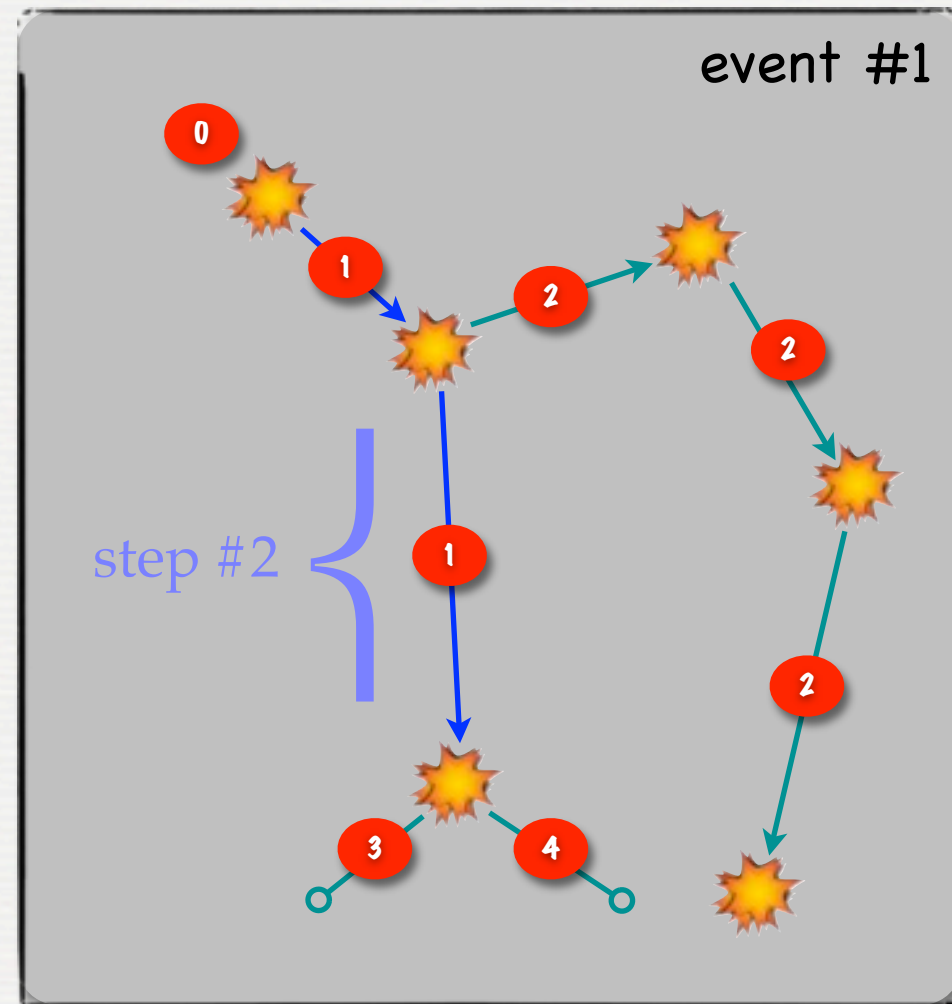
Start step # k

Stop step # k

Stop track # j

Stop event # i

Stop run # 1




k Track ID

Track stack

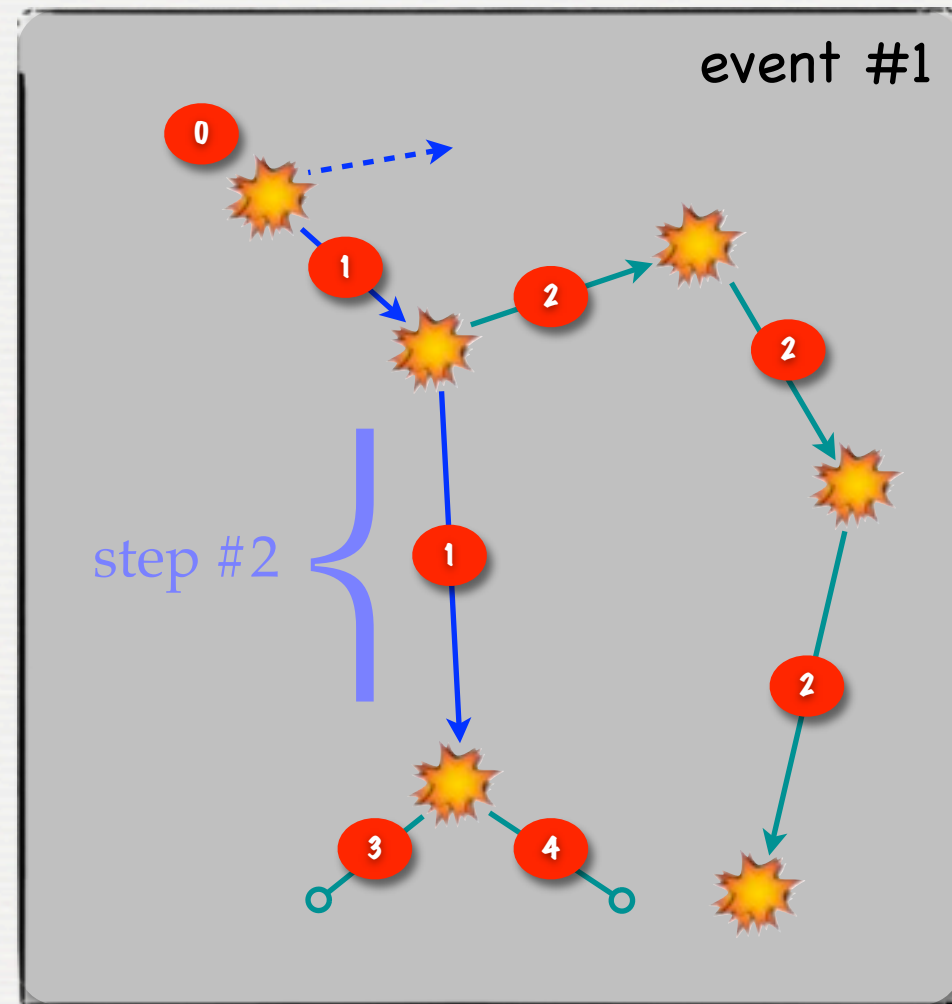
active

waiting



```
1 :  
# i
```

Stop run # 1



2
active

U

waiting

What is It? ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

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Start **track** # j

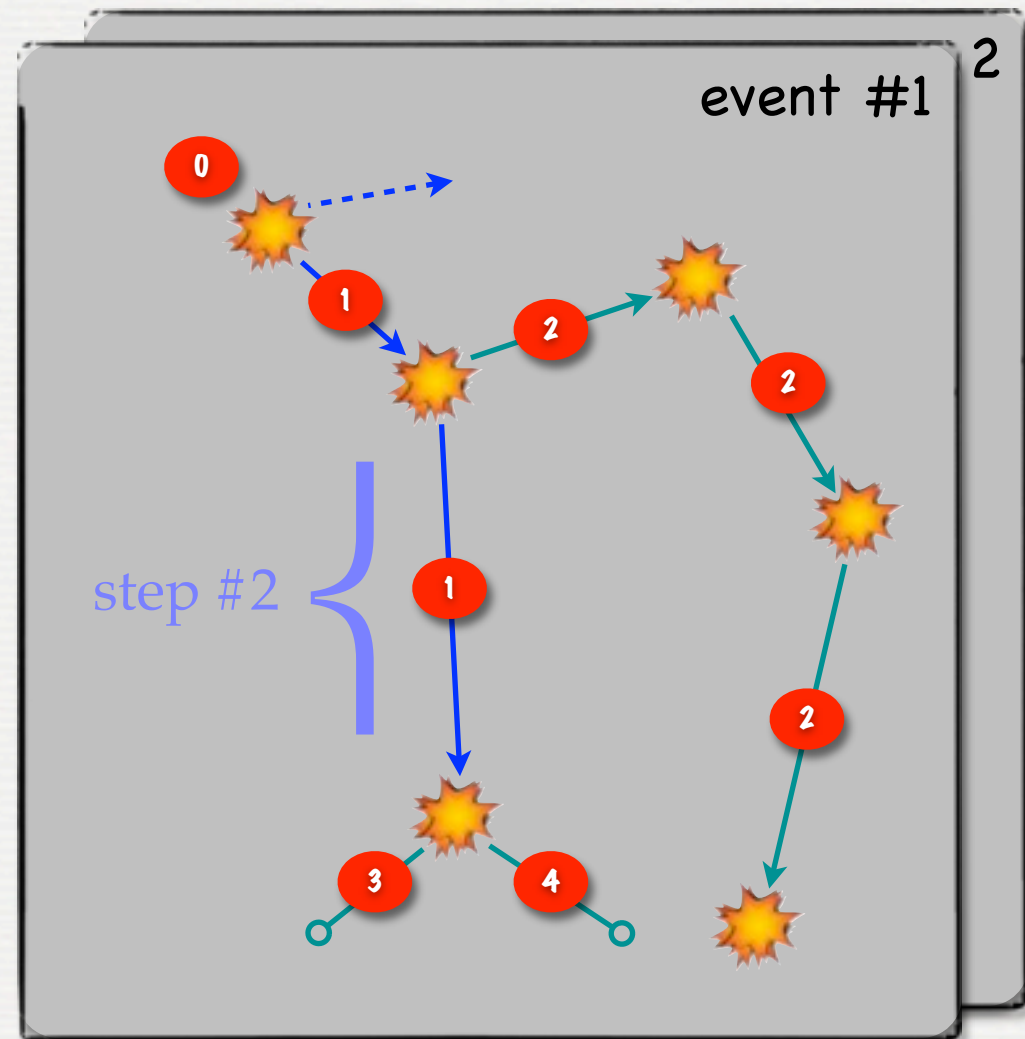
Start **step** # k

Stop **step** # k

Stop **track** # j

Stop event # i

Stop run # 1



k Track ID

Track stack

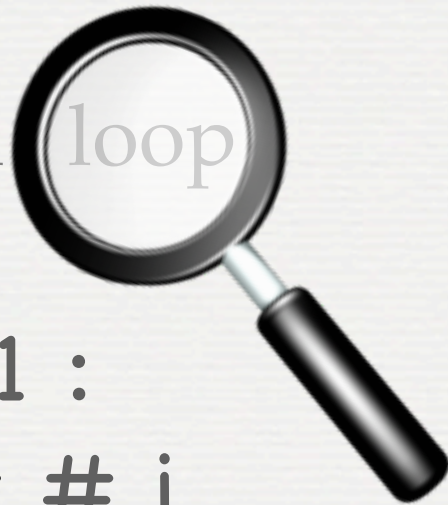
active

waiting

What is It? ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

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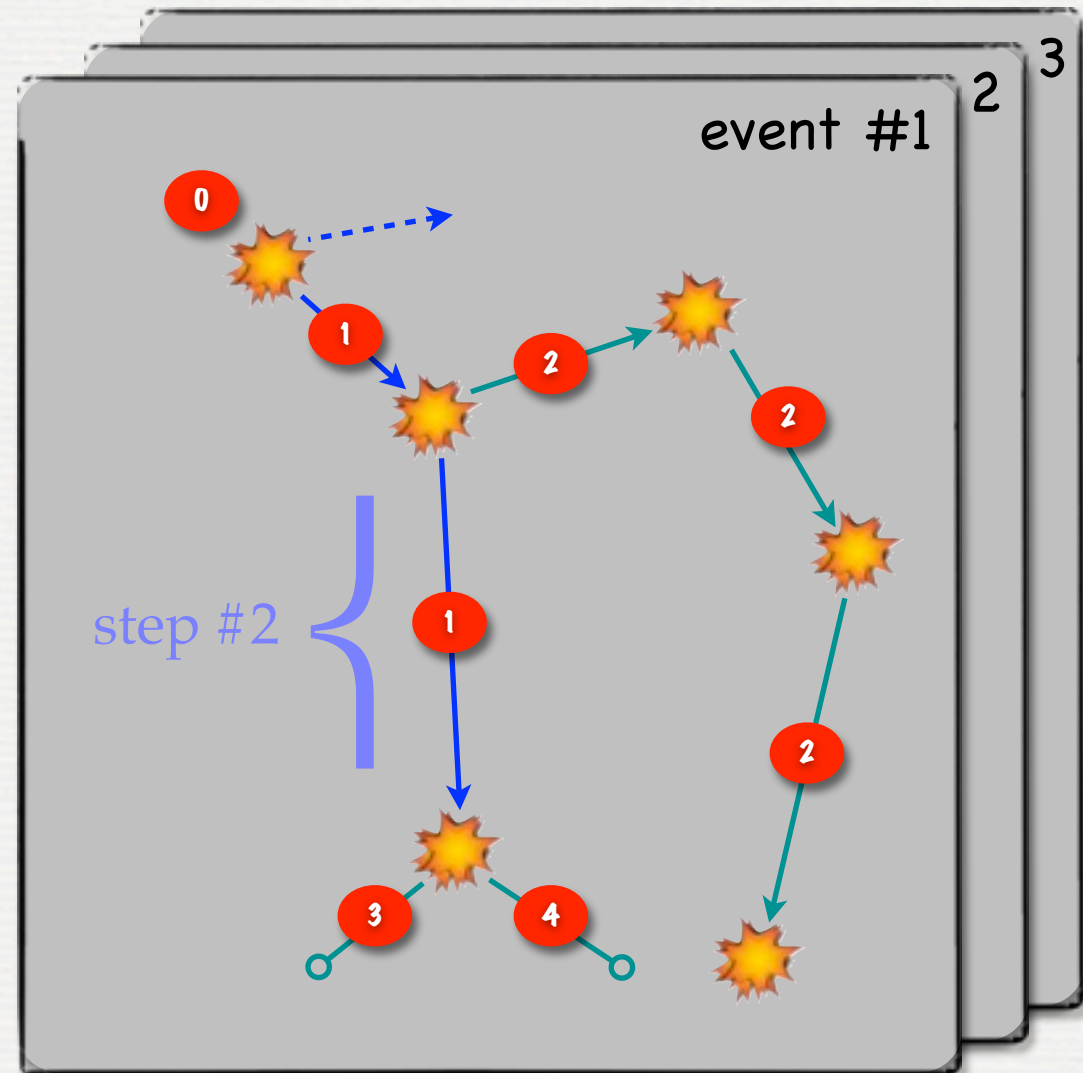
Start **step** # k

Stop **step** # k

Stop **track** # j

Stop event # i

Stop run # 1



k Track ID

Track stack

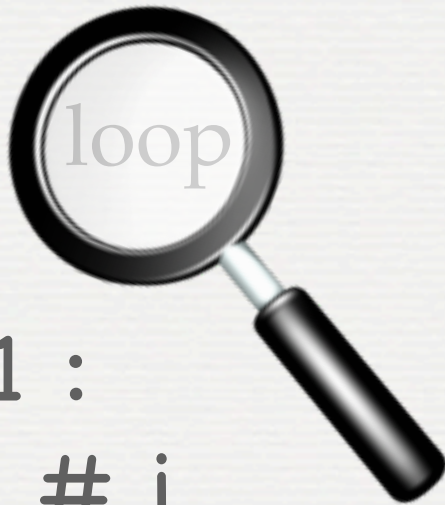
active

waiting

What is It? ALL G4Things together



'Loupe' on the main loop



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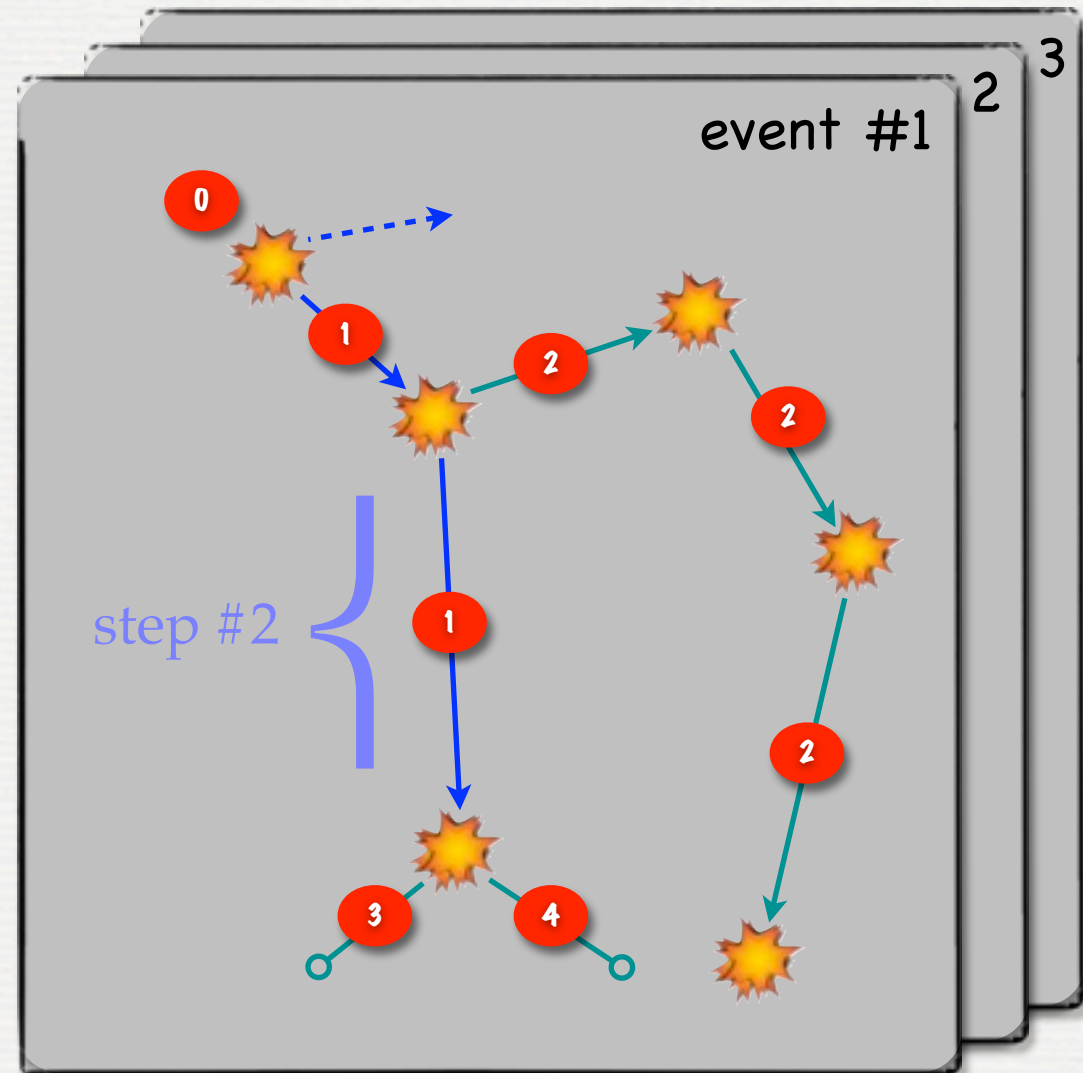
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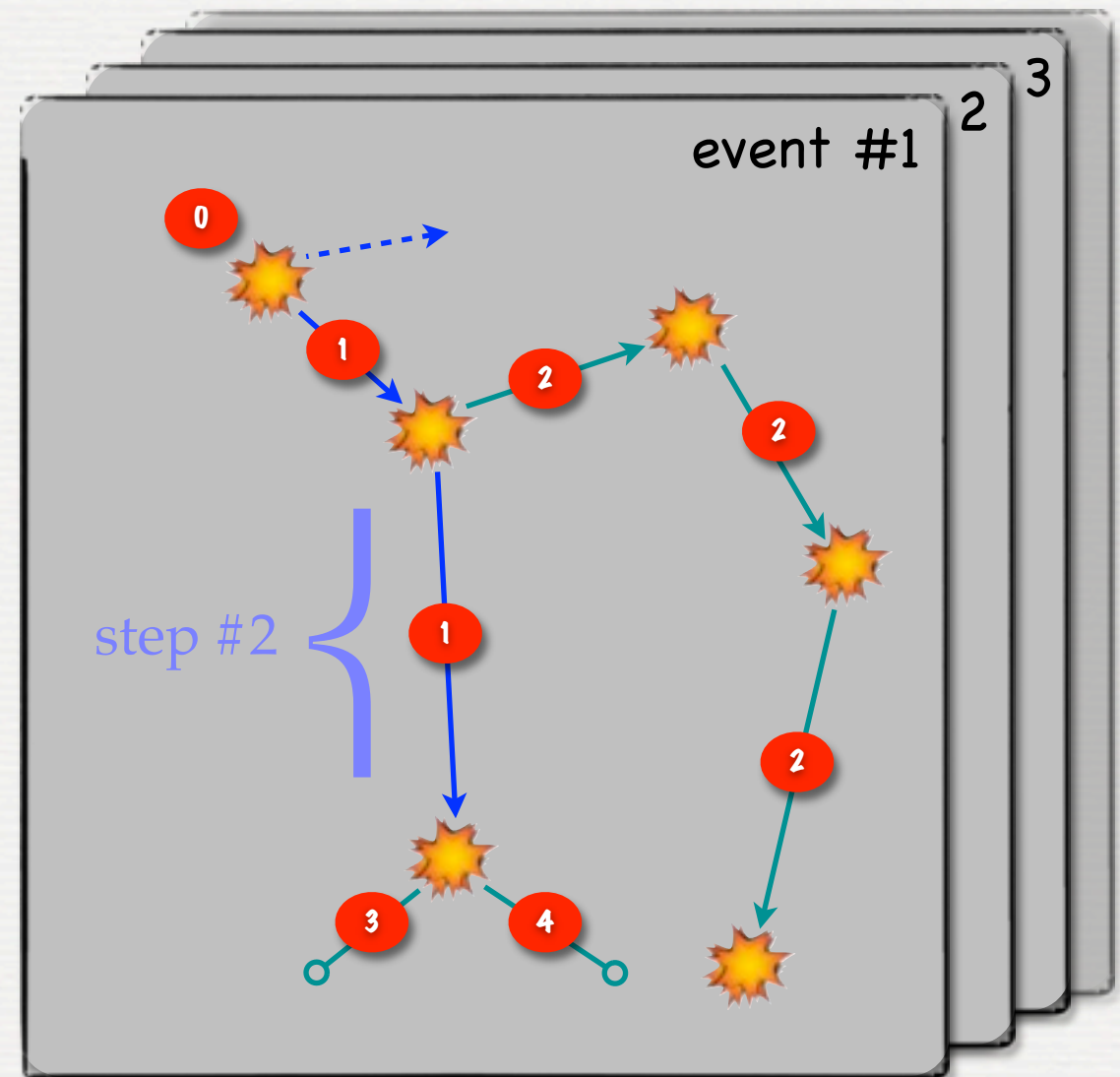
Start step # k

Stop step # k

Stop track # j

Stop event # i

Stop run # 1



2
active

active

U

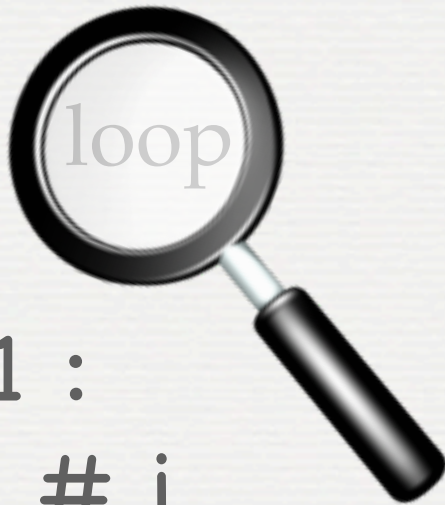
waiting

waiting

What is It? ALL G4Things together



'Loupe' on the main loop



Start run # 1 :

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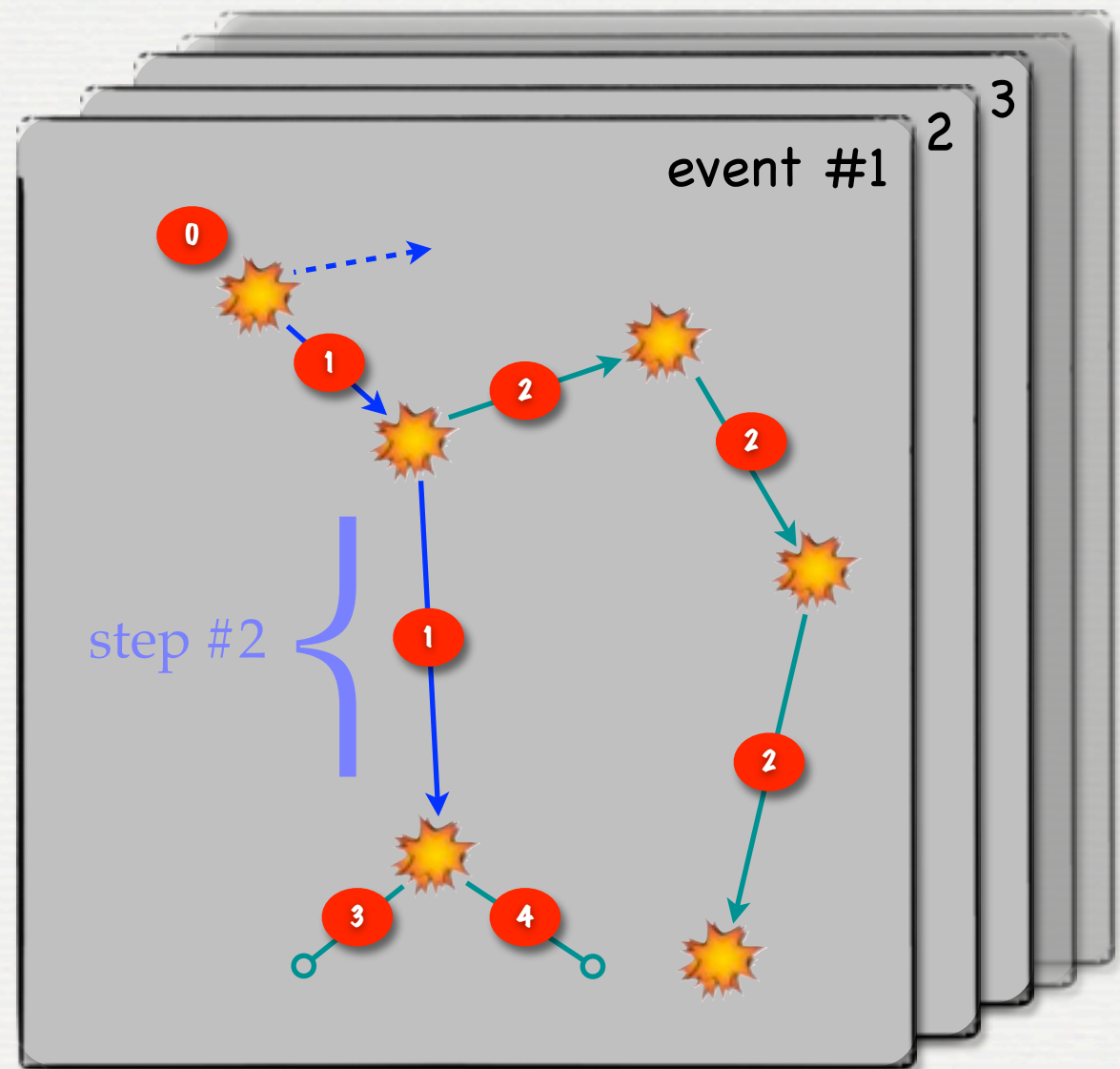
Start step # k

Stop step # k

Stop track # j

Stop event # i

Stop run # 1



 Track ID

Track stack


active


waiting



```
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```

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Start track # j

Start step # k

Stop step # k

Stop track # j

Stop event # i

Stop run # 1



Track stack

active

waiting

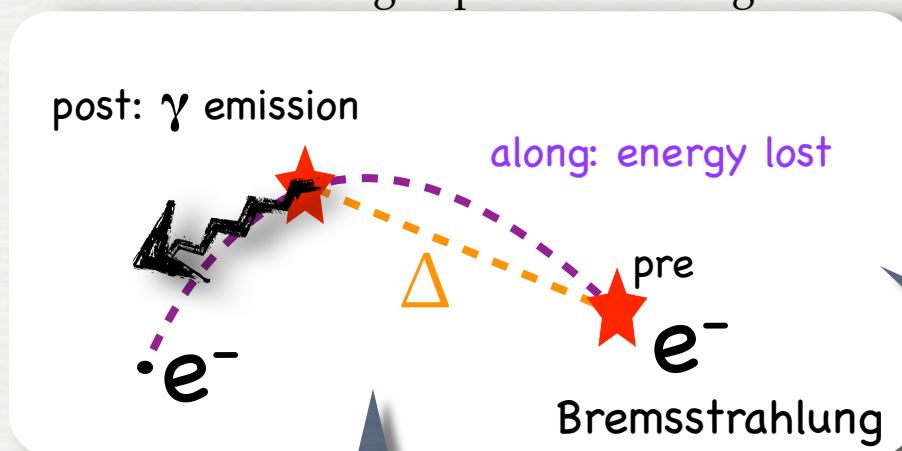
What is It?

Some remarks about steps



★ G4Step do not match necessarily the real trajectory

same remark for charged particles in magnetic fields



★ G4StepPoint: one Pre, one Post

△ G4Step: store delta information

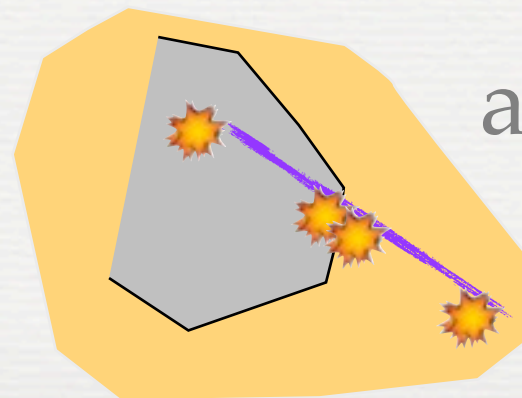
once a process is selected:

- ① all AlongStep are applied
- ② PostStep of the selected

in G4, distinctions between:
Along, PostStep, AtRest
processes

★ Fictive G4Step introduced

at boundaries



What is It? Some remarks about steps



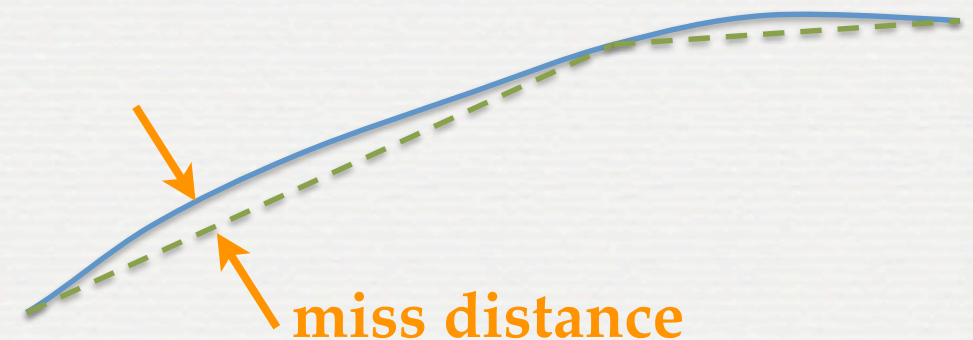
- ★ In order to propagate a **particle inside a magnetic and/or electric field**, the equation of motion of the particle in the field is solved
- ★ The *Runge-Kutta* method for the integration of the ordinary differential equations of motion

- ★ In specific cases other solvers can also be used:

In a uniform field, using the analytical solution

In a nearly uniform field (BgsTransportation)

In a smooth but varying field, with new RK+helix



- ★ Knowing the **trajectory**, G4 breaks up this curved path into **linear chord segments**

➔ The chord segments are chosen so that they closely approximate the curved path

➔ The chords are used to interrogate the Navigator, to see whether the track has crossed a volume boundary

➔ The accuracy is controlled using a parameter called the '**miss distance**':

default 3mm

it is a **measure of the error** in whether **the approximate track intersects a volume**

to be adapted for your physics ...

What is It? Some remarks about steps



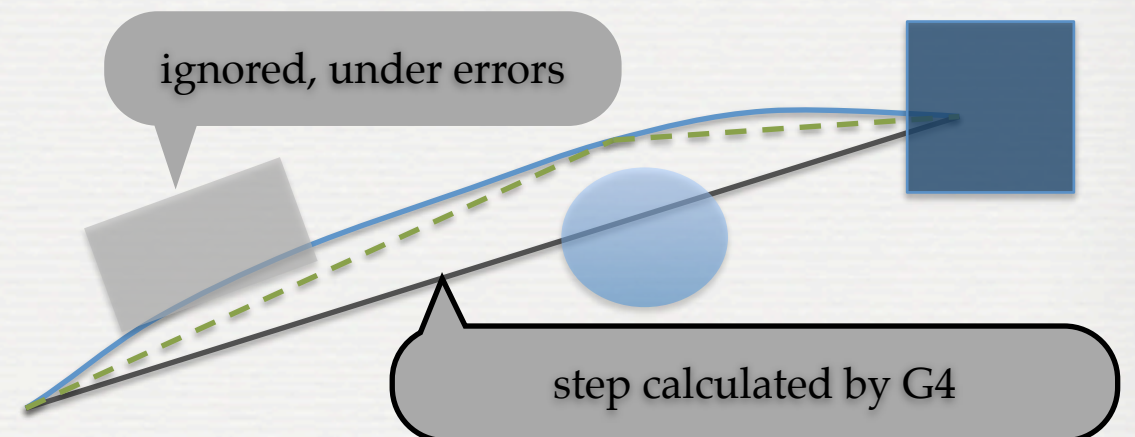
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Geant4 introduces 'cuts'

- To avoid infrared divergence for electromagnetic processes
 - ▶ for gammas, electrons and positrons
- It is a distance (1.0 mm) converted to energy for each material
- It is not a tracking cut (i.e. stop tracking if step < 1.0mm)
 - ▶ Geant4 tracks particle down to zero kinetic energy
- It is a energy threshold*
 - ▶ above: secondaries created
 - ▶ below: just energy loss
- It could be a global, per particle or per region parameter

*at which discrete energy loss is replaced by continuous loss ... up to zero ...

Conclusions / remarks

Why? because it helps a lot !

A C++ toolkit, based on Monte Carlo method to simulate particles interactions with matter

What is It?

Second time this lecture is given

↳ feedbacks mandatory !

Geant4 version 10.0 is also there

↳ running several CPU/cores in //

↳ more tricky to handle ...



The roadmap of the week

W1: installation / running a G4 application

W2: Primary generator, GPS, physics list

W3: Geometries !

W4: Sensitive detectors / user's actions

w1: 3:00, Wednesday
w2: 3:00, Wednesday
w3: 4:30, Thursday
w4: 3:00, Saturday

NOW, HOW does it really work ?

